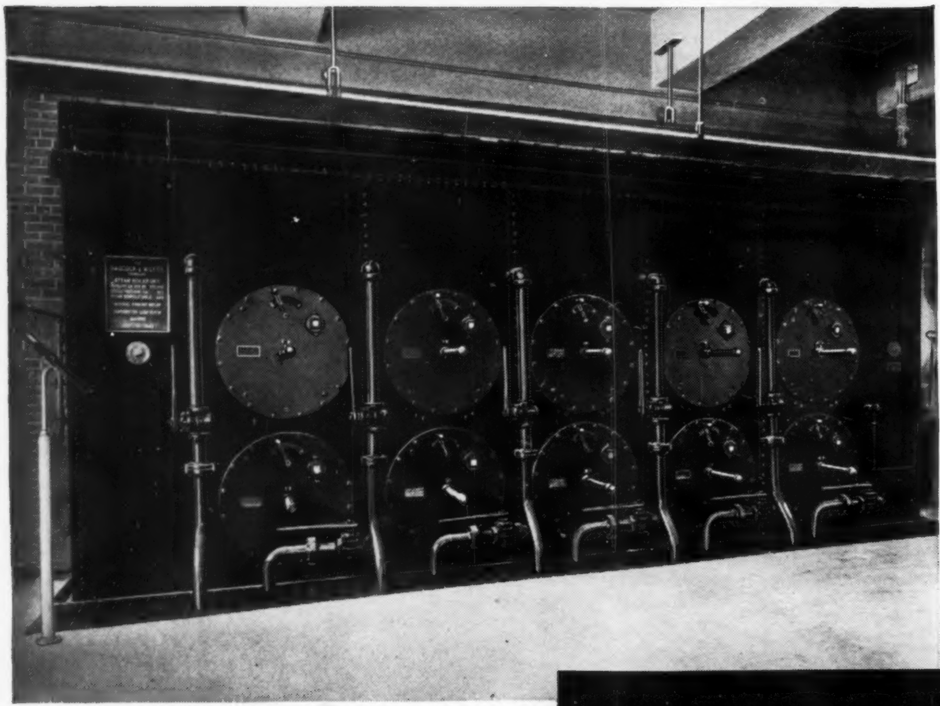
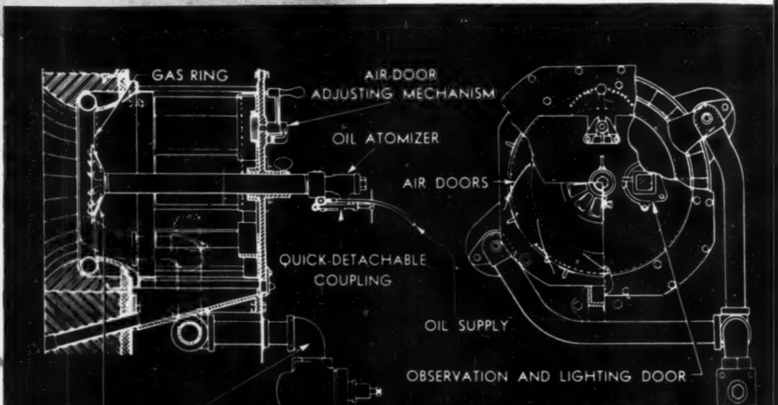
MECHANICAL ENGINEERING

NOVEMBER
1944

A.S.M.E. ANNUAL MEETING — NEW YORK, N. Y. — NOVEMBER 27 - DECEMBER 1, 1944



Combination fuel gas and oil burners of this type are installed on boilers at Lake Charles.



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MECHANICAL ENGINEERING

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MECHANICAL ENGINEERING

November
1944

GEORGE A. STETSON, *Editor*

Disarmament of Germany

During the summer *The Economist* (London) expressed in a leader entitled, "Terms for Germany," a realistic but then unpopular view of peace terms for Germany. This leader aroused much controversial discussion, and it has been followed, week by week, by letters from readers expressing a variety of opinions.

It is natural that the first of these letters should be harshly critical of *The Economist's* point of view; but as other readers have noted the trend of the criticisms, they have expressed, if not full agreement with this century-old magazine, at least an understanding of the position taken in its leader. Furthermore, a reading of the correspondence reveals that many, even of those who propose the harshest terms—terms that would mean the utter destruction of Germany as Carthage was destroyed by the Romans—recoil at the implications of their proposals and admit that not all such terms can be imposed in the twentieth century.

As this is being written, with the bombardment of Aachen in progress following a refusal to surrender, there is an indication that the Germans may have elected utter destruction in preference to making the best of their desperate plight. If so, the question of a Carthaginian peace, as *The Economist* calls it, may become academic because, by the time the peace framers will have had an opportunity to present their terms destruction may have become a *fait accompli*. Reason—if reason can be invoked in conditions which involve the Nazis—counsels that destruction by Allied military might will not extend to this tragic and complete conclusion and that the victors will still have an opportunity to demonstrate that they are conquerors but not destroyers.

Because *The Economist's* leader has stirred up so much controversy and has been referred to so frequently in this country in discussions about what to do with Germany, a brief summary should be of interest.

The leader (editorial in our parlance), which appeared in the issue of August 12, notes that even though no policy for Germany has been announced by the British Government, "semiofficial statements, declarations from the smaller Allies, rumors, and press reports all point toward a peace with indemnities, reparations, annexations of territory, and transfers of population," which, it asserts, "add up to a Carthaginian peace."

Avoidance of the recurrence of war, *The Economist* contends, is the aim of a peace treaty. It is admitted that other aims enter in—"the punishment of the guilty, the reversal of injustice, the restitution of damage done." By no other criterion than the prevention of further war can the effectiveness of a proposed treaty be judged—prevention "not perhaps in perpetuity, but at least for a reasonable span, the full lifetime of a man, or the passage of a century." And judged by this standard, *The Economist* declares, "the treaty apparently proposed for Germany is open to one verdict only. It will be a very bad treaty." Although "fringes of entirely German land" have been transferred to Germany's neighbors, its population will still be some seventy million. Economically crippled and militarily weak, "its sense of outrage and grievance will lead it to devote its entire national energies to undoing the peace." Should this condition prevail, it follows "that the peace will have to be maintained by force—and force means, literally, the victors' readiness to go to war, whatever article of the treaty may be violated." This violation will not come immediately but only when the Germans will have recovered sufficient strength. But after the war, argues *The Economist*, two distinct trends of opinion in Great Britain and the United States "will weaken the two nations' determination to enforce all the treaty all the time." The first is "isolationism tending unconsciously toward pacifism." The second is "idealist and liberal," statesmen and publicists who would, by 1955, be "profoundly disturbed by the 'harshness and injustice' of the Allied settlement." Thus the conclusion is reached that "the objection to a Carthaginian peace for Germany is not that it would be unjust—nothing could be unjust to the Nazis—but that it would raise to a maximum the Germans' desire for revenge and reduce to a minimum the British and American willingness to uphold the settlement—in short, it would produce the perfect conditions for another explosion. The test is not moral but pragmatic; not whether the Germans deserve it but whether it will work."

The remainder of the statement, thus briefly summarized, is an expansion of this conclusion to demonstrate the reason for asserting that "to plead for a 'moderate' peace is not to plead for leniency for the Germans, but for the direct opposite, for a peace that will be enforced upon them." And in answer to the criticisms of its stand leveled against it by its correspondents, *The Economist* has reiterated the statement, "We must not promise what we will not perform," a view which, it asserts, has not been opposed by its critics.

Analyses of the underlying causes of war in Europe and suggested conditions of disarmament and peace, which are among the constructive contributions contained in the letters brought forth by *The Economist's* leader, lie in fields in which engineers have no more competence and authority than any other group of intelligent citizens. However, one correspondent made a suggestion that does lie within the more particular province of the engineer. It is that "a complete prohibition of the manufacture of ferro-alloys and the control of imports of these materials, together with a total ban on imports of the ores of the special metals [i.e. tungsten, vanadium, molybdenum,

chromium, and nickel] would effectively prevent the production of armaments and ensure that Germany's wars are not repeated."

Attention has been directed to *The Economist* leader and the controversy over it not only because it is possible to consider both with reasonable objectivity owing to the fact that American politics are not directly involved, but also because it and the suggestion about control of metals in postwar Germany afford a background against which to assess the program for industrial control of postwar Germany recommended by the presidents of five national engineering societies in the United States, the A.S.C.E., A.I.M.E., A.S.M.E., A.I.E.E., and A.I.Ch.E. This program, with the text of a letter transmitting it to the Secretary of State, will be found on page 748 of this issue.

The program recommended by the five presidents, which has been favorably received by the press to whom it was released late in September, should be read in its entirety. No attempt at summarizing the entire document will be made save to mention briefly the steps recommended to eliminate Germany's capacity to make war. They amplify the suggestion quoted from *The Economist's* correspondence although there is, of course, no other connection with it. The steps recommended are:

"1 Eliminate all synthetic-oil capacity and prohibit the reconstruction of plants and the importation of oil beyond normal peacetime inventories. . . .

"2 Eliminate 75 per cent of Germany's synthetic-nitrogen-plant capacity and prohibit reconstruction of plants and all importation of nitrogen compounds. . . .

"3 Eliminate 50 per cent of Germany's steelmaking capacity in those categories of plants which are most capable of producing essential war materials such as heavy forgings and high-alloy steels. Control imports of manganese, chromium, nickel, and tungsten which are practically nonexistent in Germany. Also prohibit importation of iron ore, flux material, steel, and steel products beyond normal peacetime inventories.

"4 Eliminate aircraft plants and equipment. Aluminum and magnesium are the raw materials required for airplane manufacture. There are no important bauxite deposits in Germany. Importation should be prohibited. Alumina and aluminum plants should be destroyed and importation of aluminum ingots beyond prewar peacetime needs should be prohibited.

"If any *one* of these steps were taken," the presidents assert," war could not be waged nor prepared for. Taking all four would afford ample assurance against war."

Like *The Economist*, the five presidents run the risk of being misunderstood as urging a "soft" peace. However, a little reflection should convince one that these terms are anything but soft for a war-minded industrial nation. They avoid the creation of an "economic vacuum" and they afford the opportunity for the development of a peacetime economy essential to the welfare of Europe and the rest of the world, provided those upon whom they would be imposed are determined to make the best of their opportunities. They leave many questions of world peace unanswered, but most of those questions are not in the province of the engineer. They require also that "we do not promise what we will not perform."

Should the recommendations be adopted in whole or in part, eternal vigilance would be necessary to enforce them over a period of years. These are harsh terms. Undoubtedly, with the passage of years, the Germans would begin to whittle away at them with the object of obtaining a concession here, a relaxation there, and in this they would probably be aided by the isolationists and pacifists on one hand and the idealist and liberal statesman and publicists on the other who would either be indifferent to the dangers of relaxation or would again begin to talk about "harshness and injustice." To these groups realism demands that we add those who would profit by supplying raw materials to Germany.

At least one other danger must be guarded against. When men are balked in the attainment of their objectives by circumstances beyond their control they devise new ways of beating the devil around the stump. In the past Germany has given remarkable demonstrations of her ability to overcome handicaps of this character by resorting to science, research and technological development, and native ingenuity. The recommendations of the five presidents seem effective restraints today. Who can say what tomorrow will bring forth. Research too must be watched and, most important, must not lag in the countries dedicated to the maintenance of peace and the growth of democratic ways of life. If support of research programs is withheld, we shall stagnate and grow indifferent while our opponents prepare for our overthrow. Competition under private enterprise is likely to keep the lamp of industrial research burning. But funds also must be made available so that those who are charged with the protection of our lives, our homes, and our commerce may investigate the military significance of every discovery. Thus we shall be prepared to defend ourselves against any future "secret weapons," however innocent they may seem on initial appearance.

Since the foregoing was written the September 22 issue of *Engineering* (London) has been received. In a long editorial entitled, "The Disarmament of Germany," it is contended that "the key personnel required for a disarmament commission must be the engineers and technicians, both Service and civilian, qualified in handling and producing war material. . . . The difficulty is that it is the same corps of engineers and technicians that will be needed to continue the supervision of the material preparations for the overthrow of Japan. . . ." Thus, it is argued, "it appears probable, therefore, that the British and American contingents of whatever disarmament commission is established will be too small for the vast task they have to perform, at any rate initially. The settling of priorities for the work is . . . a matter of great importance."

Calling naturally for the destruction of armaments, the editorial continues: "The disruption of the German capacity for producing armaments is of far greater importance than the disposal of existing munitions. It is also a great deal more difficult to accomplish, for reasons which are probably not fully understood outside engineering circles."

Among other suggestions it is stated that, "the whole of German industry will require combing with a view to the elimination of jigs, fixtures, tools, and gages, special to the production of armaments," the cutting down or the elimination of the machine-tool, optical, and radio industries, and the destruction of munition factories, state arsenals, and commercial concerns like Krupp's.

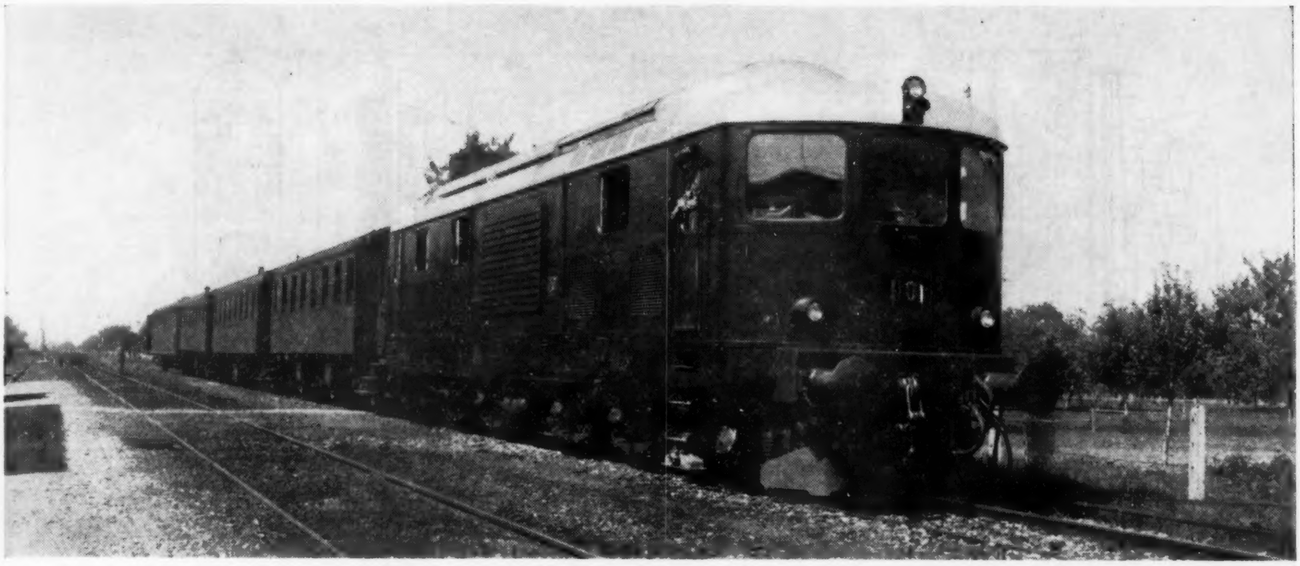


FIG. 1 2200-HP GAS-TURBINE LOCOMOTIVE OF SWISS FEDERAL RAILWAYS WITH SHORT TRAIN

GAS-TURBINE LOCOMOTIVES *for* MAIN-LINE SERVICE

By PAUL R. SIDLER

RESIDENT ENGINEER, BROWN BOVERI & CO., LTD., NEW YORK, N. Y.

IN A previous paper and subsequent comment,[1] the author gave a brief description and test data of the gas turbine-electric locomotive of 2200 hp built by his company for the Swiss Federal Railways. As an introduction to the present paper a brief discussion of the operation of the Swiss gas-turbine locomotive during the intervening period will be given.

OPERATING RESULTS OF SWISS GAS-TURBINE LOCOMOTIVE

Between May, 1943, and June, 1944, this locomotive was operated on a regular daily schedule over one of the longest secondary lines in Switzerland, which is still not electrified. This line has a length of 47 miles and 21 stops, with light mixed passenger and freight traffic. The run includes switching operations at many stations, also numerous curves with resulting low average speed. This is far from ideal for a locomotive which is basically intended for long high-speed runs with few stops. During this period of service, the locomotive covered about 50,000 miles, far less than it could have traveled had oil fuel been freely available, but again much more than could have been hoped for, considering the severe wartime shortages in Switzerland.

This run did not provide opportunities for trying out sustained operation at or near maximum speed, but it did offer occasions for starting, acceleration, and stopping at much more frequent intervals than would occur under more normal circumstances. It was therefore a much more severe tryout of the power plant and the control equipment than might be judged from the total mileage alone. The number of control operations performed would normally be reached only in long-distance runs, aggregating at least 10 times the total mileage covered.

Fig. 1 shows the locomotive with a light train at one of the stations along its daily route. This year of regular service confirmed the results of the earlier trial runs in regard to guaranteed performance. All requirements have been fully met, no major disturbances of any kind have occurred. Minor adjustments could always be completed during scheduled waiting periods. Therefore, the availability record is excellent.

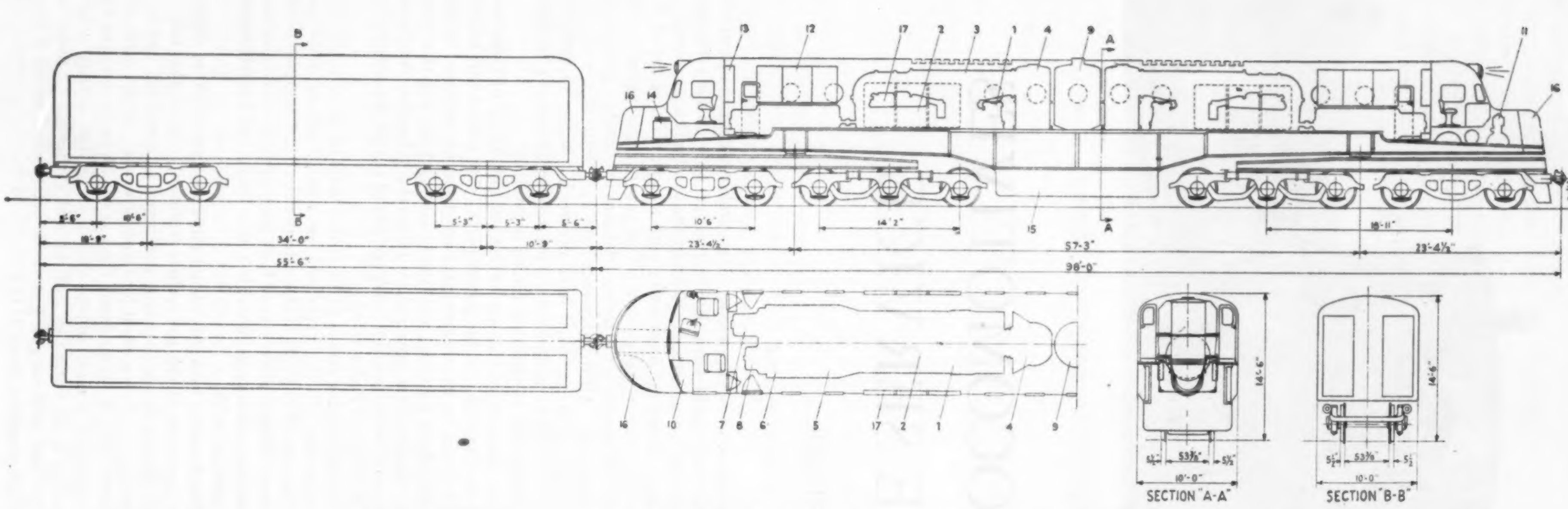
The operating crews appreciate the simplicity of operation and the flexibility of the power plant. In view of this record, the locomotive has meanwhile been definitely accepted by the Swiss Federal Railways and is now in the service together with other locomotives powered by internal-combustion machines. The only limitation of its mileage record is still the continuing oil shortage in Switzerland.

The gas-turbine power plant of the Swiss locomotive already incorporated all the experience previously gained with gas turbines in other applications. In the electrical equipment and controls, Brown Boveri could look back upon several decades of consistent and successful work in the electric and Diesel-electric locomotive fields.

Based on this background and using the data collected during the operation of the gas-turbine locomotive since the fall of 1941, Brown Boveri has now developed a "standard" gas turbine-electric power plant for locomotive use. In its main elements it uses the same frame sizes as the Swiss locomotive but incorporates several improvements in design details which result in a net output of 2500 hp and a thermal efficiency of 20 per cent without going into the yet largely untried field of gas temperatures above 1112 F.

[1] "Gas-Turbine Locomotive With Electrical Transmission," by P. R. Sidler, Mechanical Engineering, vol. 65, 1943, pp. 261–266.

Contributed by the Oil and Gas Power and Railroad Divisions for presentation at the Annual Meeting, New York, N. Y., Nov. 27–Dec. 1, 1944, of The American Society of Mechanical Engineers.



1 Gas turbine
2 Turbocompressor
3 Air preheater
4 Combustion chamber
5 Reduction-gear set
6 Main generator group
7 Auxiliary generator
8 Brake-excitation generator
9 Steam boiler for train-heating
10 Storage battery
11 Auxiliary Diesel generating set
12 Electrical control apparatus
13 Control apparatus in engineer's cab
14 Air-brake compressor set
15 Water tank for steam boiler
16 Fuel-oil tanks, main supply from tender
17 Lubricating-oil radiators

FIG. 2 5000-HP FREIGHT AND PASSENGER GAS-TURBINE LOCOMOTIVE WITH FUEL-OIL TENDER
(See Table 1 for data.)

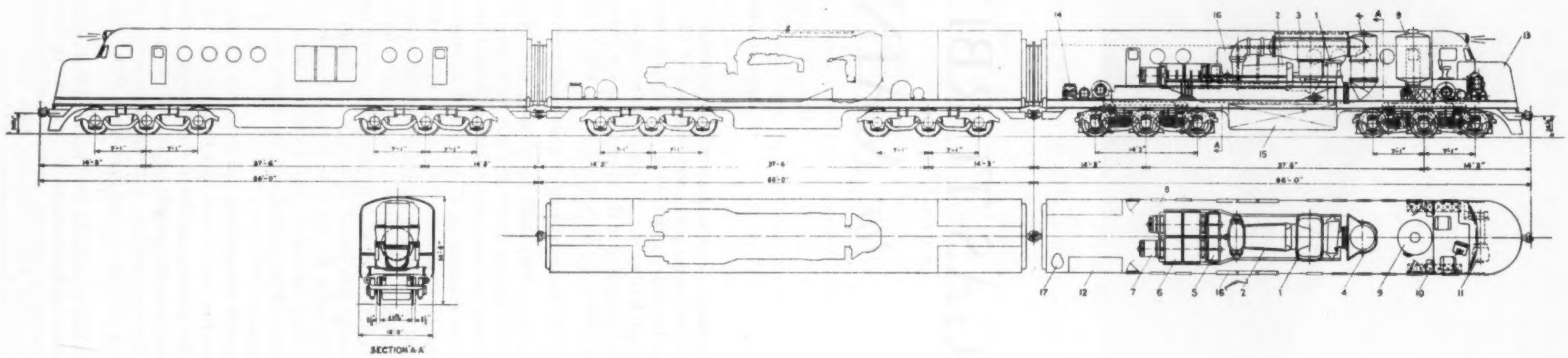
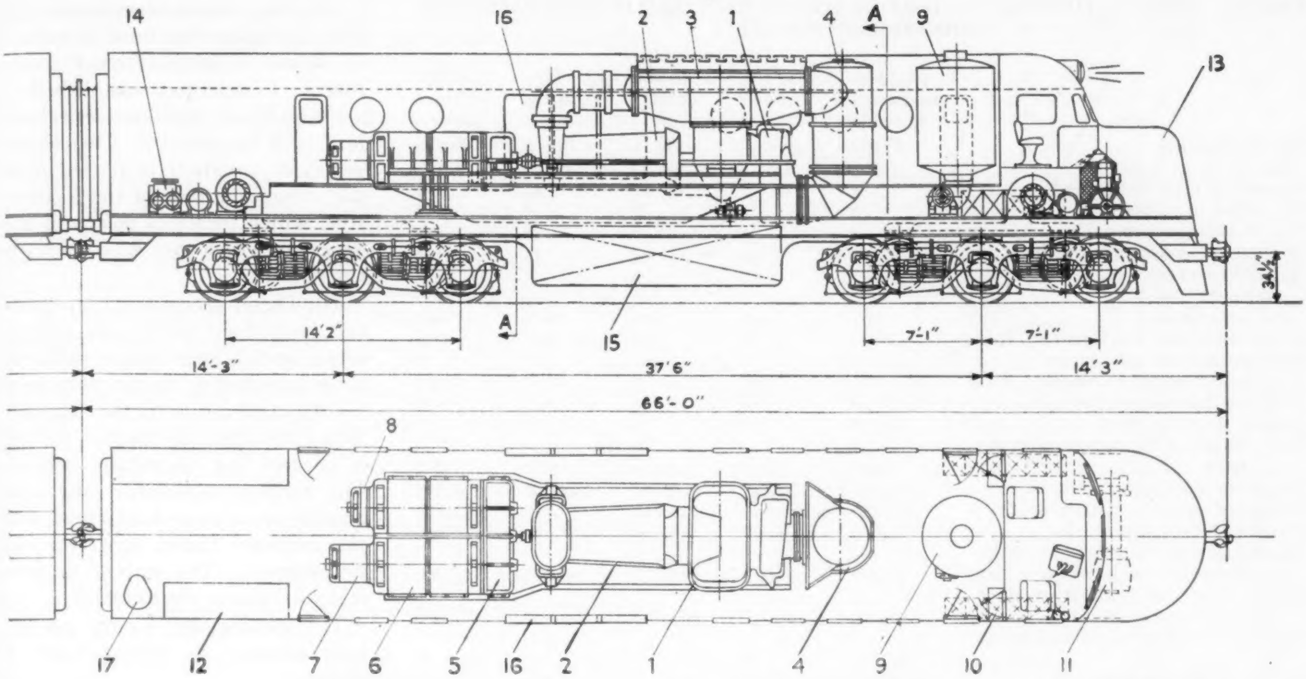


FIG. 3 7500-HP PASSENGER AND FREIGHT GAS-TURBINE LOCOMOTIVE
(For details of end unit see Fig. 3*a*.)



1 Gas turbine
2 Turbocompressor
3 Air preheater
4 Combustion chamber
5 Reduction-gear set
6 Main generator group
7 Auxiliary generator
8 Brake-excitation generator
9 Steam boiler for train heating
10 Storage battery
11 Auxiliary Diesel generating set
12 Electrical control apparatus
13 Train control, etc.
14 Air-brake compressor set
15 Water and fuel tank
16 Lubricating-oil radiators
17 Toilet

FIG. 3*a* 2500-HP END UNIT OF 7500-HP LOCOMOTIVE OF FIG. 3

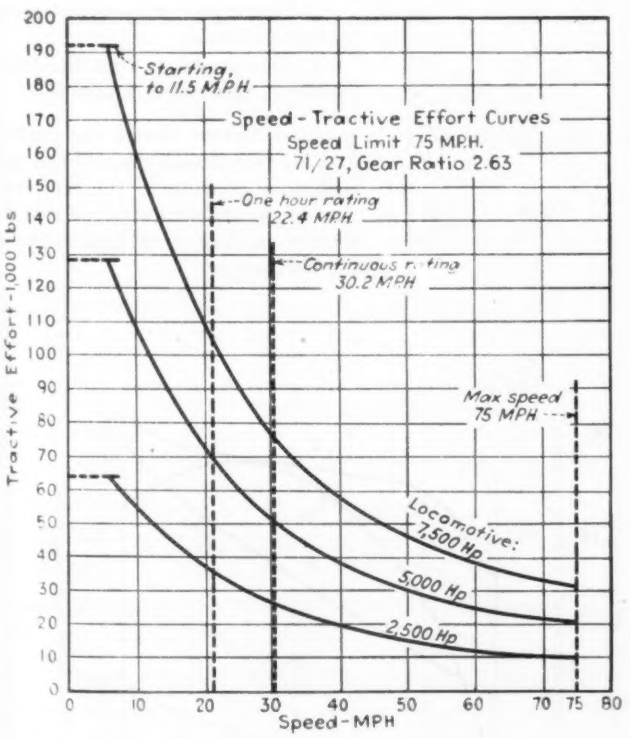


FIG. 4 TRACTIVE-EFFORT CURVES FOR BOTH PASSENGER AND FREIGHT SERVICE; 75 MPH LIMIT

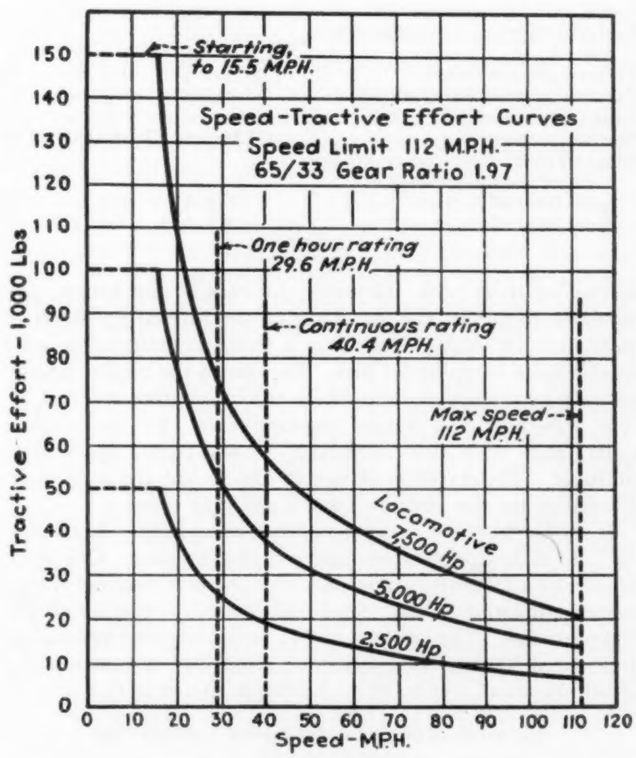


FIG. 5 TRACTIVE-EFFORT CURVES FOR BOTH PASSENGER AND FREIGHT SERVICE; 112 MPH LIMIT

Also, it has been realized that American railroad practice requires heavier electrical equipment, both in generators and traction motors, than is the case in Europe.

The "standard" power plant of 2500 hp can be used singly or in multiple in a wide variety of combinations. Two specific cases will be considered more closely, as follows:

1 Passenger and freight locomotive of 5000 hp, one unit with two "standard" power plants, for double-end operation. The layout is shown in Fig. 2, and the main characteristics are given in Table 1. It should be especially noted that the tender, shown in Fig. 2, is not required when the locomotive is in

TABLE 1 GENERAL DATA OF GAS-TURBINE LOCOMOTIVE USED IN BOTH PASSENGER AND FREIGHT SERVICE

Item	5000 Hp, single unit and tender	2500 Hp, front unit	5000 Hp, front and center unit	5000 Hp, both end units	7500 Hp, all three units
Outline drawing	Fig. 2	Fig. 3(*a*)	Fig. 3	Fig. 3	Fig. 3
Gage of track, ft-in	4-8 1/2	4-8 1/2	4-8 1/2	4-8 1/2	4-8 1/2
Number of axles (with tender)	14	6	12	12	18
No. of driving axles	8	4	8	8	12
No. of driving motors	8	4	8	8	12
Diameter of driving wheels, in	44	44	44	44	44
Wheel base of trucks:					
4 wheels (ft-in.)	10-6	—	—	—	—
6 wheels (ft-in.)	14-2	14-2	14-2	14-2	14-2
Distance between truck centers, ft-in.	18-11	37-6	37-6	37-6	37-6
Distance between cab centers	57-3	—	—	—	—
Total wheel base of locomotive, ft-in.	87-0	51-8	117-8	117-8	183-8
Length of locomotive, alone, ft	98	66	132	132	198
Length of tender, ft-in	55-6	—	—	—	—
Total length of locomotive with tender, ft-in	153-6	66-0	132-0	132-0	198-0
Weight of mechanical parts, lb	264,290	172,445	329,890	344,890	502,335
Weight of electrical equipment, lb	137,110	68,555	137,110	137,110	205,665
Weight of thermal plant, lb	113,600	59,000	118,000	118,000	177,000
Weight of fuel, crew, sand, boiler feedwater, etc., on locomotive, lb	35,000	30,000	75,000	60,000	105,000
Total weight of locomotive alone, ready for service, lb	550,000	330,000	660,000	660,000	990,000
Weight of mechanical part of tender, lb	90,000	—	—	—	—
Weight of fuel on tender, lb	120,000	—	—	—	—
Total weight of tender, lb	210,000	—	—	—	—
Total weight of locomotive and tender lb	760,000	—	—	—	—
Adhesive weight of locomotive, lb	440,000	220,000	440,000	440,000	660,000
Weight per driver, lb	55,000	55,000	55,000	55,000	55,000
Capacity of fuel on locomotive, gal	500	2,300	6,800	4,600	10,000
Capacity of fuel on tender, gal	16,000	—	—	—	—
Fuel consumption at full load, gph	534	267	534	534	800
Fuel consumption at one-half-load, gph	272	136	272	272	408
Fuel consumption at one-quarter load, gph	174 or 136	87	174	174	261
Thermal-efficiency curve	Figs. 8 or 9	Fig. 8	Fig. 8	Fig. 8	Fig. 8
Capacity of steam boiler, lb per hr	3600	3600	3600	7200	7200
Capacity of water, gal	3500	1100	2000	2200	2200
Traction motor type	GLM735S	GLM735S	GLM735S	GLM735S	GLM735S
Speed-tractive effort curves for passenger and freight service:					
Speed limit of 75 mph	Fig. 4	Fig. 4	Fig. 4	Fig. 4	Fig. 4
Speed limit of 112 mph	Fig. 5	Fig. 5	Fig. 5	Fig. 5	Fig. 5

service on short runs. However, for runs of any length, particularly from the Hudson River to the Mississippi River or from there on to the West Coast, a tender is preferred in order to eliminate stopping for fuel. The size of the tender depends entirely upon the service in which the locomotive operates.

2 Passenger and freight locomotive of 7500 hp in three units, each with one "standard" power plant, operated in multiple. The layout is shown in Fig. 3, and the main characteristics are also given in Table 1 and Figs. 4 and 5.

It should be noted that the two end units in Fig. 3 (see Fig. 3*a*), are fully equipped for independent operation. One alone represents a 2500-hp locomotive. One end unit together with a center unit forms an articulated 5000-hp locomotive for single-end operation. The two end units coupled together produce an articulated 5000-hp locomotive for double-end operation if this should be found preferable to the design shown in Fig. 2.

THERMAL PLANT OF GAS-TURBINE LOCOMOTIVES

The prime-mover plant consists essentially of the gas turbine, an air compressor directly coupled to it, an air preheater, a combustion chamber, and the necessary auxiliary equipment, such as fuel-oil pumps, lubricating-oil pumps, speed and fuel-oil regulators, gas-turbine shaft-turning device, and the necessary safety appliances that are essential for the protection of the unit against overspeed, too high temperature, or lack of lubricating or control oil pressure.

Like any internal-combustion engine, the gas turbine must be started by means of some external power source. In order to accomplish this, a 200-hp Diesel generator set is built into each locomotive. This Diesel generator set itself is started from the storage battery of the locomotive, which furnishes power to the generator which then acts as a starting motor.

The Diesel generator group starts the gas-turbine group and accelerates it up to a speed where sufficient air is furnished by the air compressor for the combustion of the fuel oil. When this speed is reached, fuel oil is injected and electrically ignited. The turbine accelerates now very quickly up to its no-load speed, and the auxiliary Diesel generator can be stopped. The turbine is now ready to operate the locomotive.

The starting time for the gas turbine amounts to approximately 5 minutes.

The operating characteristics of the gas turbine are shown in Fig. 6, where the four curves give the following values for the 2500-hp unit:

(*a*) Thermal efficiency in per cent.
(*b*) Speed of gas turbine.
(*c*) Temperature of gases in degrees at turbine intake.
(*d*) Pressure of air after the compressor in pounds per square inch.

Fig. 7 further shows the output and the fuel consumption of the gas turbine in relation to the temperature of the ambient air. In this illustration, the various lines indicate the following:

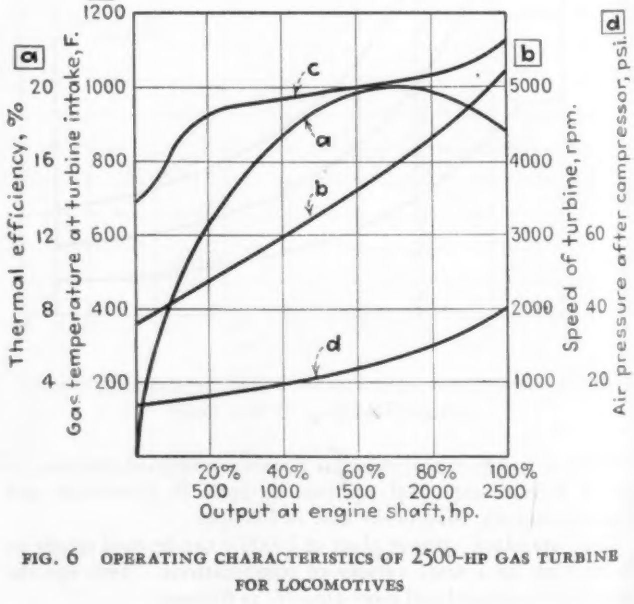


FIG. 6 OPERATING CHARACTERISTICS OF 2500-HP GAS TURBINE FOR LOCOMOTIVES

1 Per cent output of the gas turbine in terms of normal output to generator shaft.
2 Per cent input to the compressor, in the same terms as (1).
3 Thermal efficiency.
4 Fuel consumption.
5 Input of turbine to generator in terms of the normal input at 68 F.

Particularly, the group of characteristics just mentioned shows that, with decreasing ambient temperature, the output of the gas turbine increases faster than the input of the compressor. The turbine can therefore deliver a higher output to the generator at lower outside temperatures. In fact the gain is of such magnitude that the locomotive can at 32 F, if it is equipped with a heating-power generator, deliver its normal full output and a considerable amount of heating power for the same fuel consumption as it needs to deliver traction power only at about 70 F ambient temperature. This is a valuable feature of the gas-turbine locomotive which should be taken advantage of in any case where the trailing cars are equipped for electric heating.

Lubricating-oil coolers are provided in the side walls of the locomotive.

Contrary to the lubricating requirements of a Diesel engine, which may reach a high cost, the lubrication cost of the gas-turbine compressor unit is practically negligible. It will only be necessary to renew each charge of oil after approximately 10,000 hours of operation.

The gas turbine and the compressor unit contain each only two bearings that must be lubricated. There are no crankshafts, no connecting rods, no pistons that move up and down, no cylinder walls to lubricate, no camshafts with their bearings, and no valves. In short, the gas turbine is the simplest of all thermal motive-power units in use today.

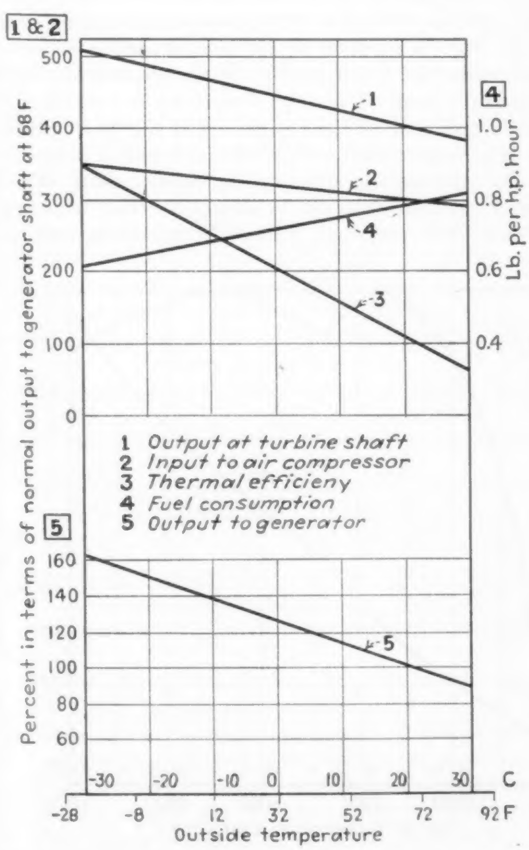


Fig. 7 Output, efficiency, and fuel consumption of a gas turbine in relation to the outside temperature

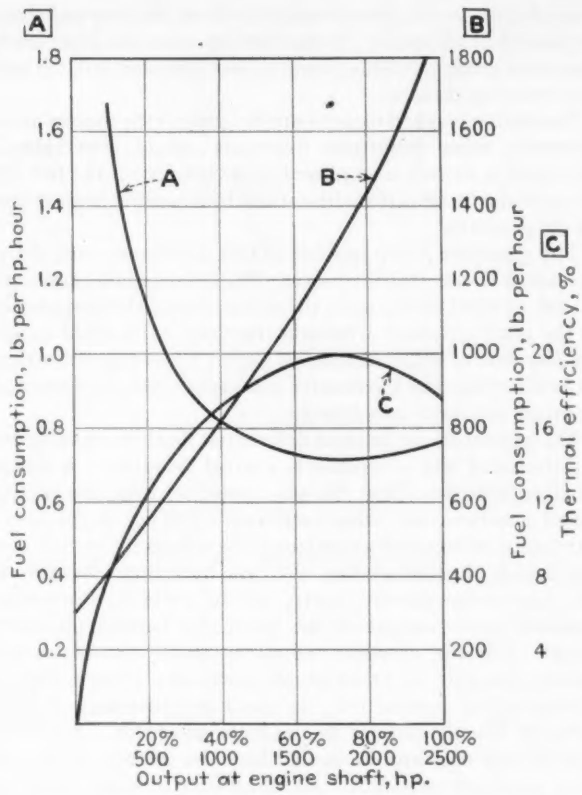


Fig. 8 Fuel consumption of 2500-hp gas-turbine locomotive

The gas turbine is normally operated with bunker C fuel oil. This oil does not lend itself to ignition at normal temperature. A fuel-oil preheater is therefore arranged above the air preheater, where it is exposed to the exhaust gases of the turbine. The gas turbine is started and for a few minutes is operated with Diesel oil. When the bunker oil has reached a temperature of about 175 to 200 F, the change-over to bunker oil is made.

The fuel consumption and the efficiency of the 2500-hp gas turbine for various loads are indicated in Fig. 8. The output of the gas turbine is regulated by setting its speed at certain values. This is accomplished by the master controller, which influences the governor. The speed governor in turn controls the fuel supply to the combustion chamber in such a manner that the speed for which the master controller is set, is obtained at the turbine shaft. The output-control system of the locomotive is simple and functions in such a way that, over a wide speed range of the locomotive, the output at the turbine set is practically constant for each selected speed point. A temperature-control device is arranged to decrease the load if the normal operating temperature of the turbine is exceeded and to increase it if the turbine operates below normal temperature. With this arrangement the gas turbine always works with its best efficiency.

Sudden heavy overloads of the gas turbine do not stop it, such as is the case with a Diesel engine; they merely lower the speed of the machine until the output-regulating device has had time to adjust the fuel-oil supply and the excitation of the main generator.

The no-load speed of the gas-turbine set is about 1820 rpm, whereas at full load it operates at about 5200 rpm.

Reduction-Gear Set. Since we do not wish to operate the generators at 5200 rpm, a gear reduction-set is arranged between the gas-turbine compressor shaft and the generator group.

Electrical Equipment. Our investigation of methods of transmitting power from the prime mover to the wheels of the locomotive has led us to adopt electrical transmission as the most

suitable one, for the power range involved, for easy and smooth regulation at all speeds. In the 2500-hp-units the direct-current generator group furnishes power to four forced-ventilated series-type traction motors.

Overload relays and motor switches protect the motors and the generator from dangerous overloads. Field weakening of the traction motors is employed in order to cover the full speed range of the locomotive without reaching unduly high voltages on the generator.

The generator group consists of four armatures, each delivering power to one traction motor. No series-parallel connection is used on the 2500-hp unit, the motors being always connected to the same generator armatures over the entire speed range of the locomotive. The absence of such a series-parallel arrangement simplifies the locomotive and assures smooth power control over the entire speed range.

The generators are built as differential machines having both a self-excited and a separately excited winding. A starting winding is used to drive the gas-turbine set from the auxiliary Diesel generator set when starting. Output regulation is accomplished mainly by regulating the separately excited winding, which, in combination with the differential winding and the temperature-control device of the turbine, maintains a constant power output of the group for various locomotive speeds. For the operation of all auxiliary circuits, such as battery charging, traction-motor ventilating groups, fuel and lubricating-oil pumps, etc., an auxiliary generator of 65-kw rating is directly coupled to the main generator. A rocking-type voltage regulator is used to keep the voltage of the auxiliary generator constant for all speeds from no load to full load.

Electric Braking. The gas-turbine locomotive lends itself readily to electric braking; in fact it is ideally suited to it. During braking, the motors furnish power to the generator, (instead of to resistors as would be necessary for other types of locomotives), which in turn drives the gas-turbine set. The air compressor absorbs all power that is delivered by the generator. The locomotive will be able to brake any train on a downgrade that it can haul up the same grade.

Traction Motors. The traction motors, which are of the forced-ventilated type, can be either of the nose-suspended or entirely suspended rigidly mounted type. In the latter case, none of their weight rests on the driving axle. A flexible disk drive is then used to transmit the motor torque to the driving wheels.

These motors have already been used in single-phase locomotives with pulsating motor torque and power of up to 1000 hp per axle, permitting the free vertical movement of the axle within the limits of the journal-box guides. Most important of all, this disk drive does not require any axle lubrication at all and does not influence the springing of the locomotive. We strongly recommend the application of this very simple unit because it protects the motor from the heavy blows otherwise imposed upon it from the axle, and it reduces the unsprung dead weight to a minimum.

We have previously mentioned that the locomotives are equipped with an auxiliary Diesel generator set of approximately 200-hp rating in order to start the gas turbine. This set is also used to feed one of the traction motors when it is desired to move the locomotive only a short distance at slow speed, such as moving it out of a shed, or to a train for coupling up, before the gas turbine has been started, or even for light switching work.

Stopping the Gas Turbine. The gas turbine is shut down by stopping the fuel-oil pump. In order to prevent the bending of the turbine shaft during the cooling-down period, a shaft-turning device is installed in the locomotive. A timing relay controls a shaft-turning motor of small output (fed from the storage battery) in such a way that the turbine shaft is turned $^1/_2$ revolution about every 30 min. This continues for a period of about 6 hr.

Mechanical Parts. The mechanical parts proposed for these engines are in accordance with standard American locomotive-construction practice.

The cab rests on a heavy underframe which is either of welded or integral-cast construction. The 2500-hp units rest on two trucks which are the 6-wheel type for freight and high-speed passenger locomotives. None of the trucks is articulated; that is, the tractive pull of the locomotives is transmitted through the cab underframe.

As shown in Fig. 2, the 5000-hp locomotive rests on four trucks, of which two have 4 wheels and the other two 6 wheels. The 6-wheel trucks and the motors installed in them are the same as those used in the 2500-hp units. Only the springs will be different on account of the different axle load. Otherwise these trucks are interchangeable for the proposed locomotive types.

The trucks are of the 4- and 6-wheel spring-bolster type having integral steel-casting frames. The axle boxes can be either of the antifriction or sleeve-bearing type. Two traction motors are mounted in each truck, the middle axle of the 6-wheel truck being an idler. Since the motors are of the forced-ventilated kind, a flexible air connection is arranged between the truck and the cab underframe, on which the motor blowers are located.

All these proposals contemplate electrical transmission. Aside from its long experience in this field, Brown Boveri also feels that in introducing a novel type of locomotive power plant it is important to eliminate any causes for disturbance which might obscure the main issue. Mechanical transmissions for the power and speed conditions necessary on a locomotive do not appear to have been in successful use for sufficiently long periods to warrant their immediate consideration. This may change at a later date after more developmental work has been completed. The electrical transmission also has the important advantage of allowing a much greater flexibility in weight distribution and particularly in limiting the axle load.

Thermal Efficiency. It is a well-known characteristic of the gas turbine that, in order to obtain high thermal efficiency at fractional loads, the speed of the compressor must be varied according to the load. When the compressor is coupled to the gas turbine on the one side and on the other side to an alternating-current generator with constant frequency, or a mechanical device requiring constant speed on the driving shaft, this desirable speed variation cannot be obtained. For such cases, Brown-Boveri has proposed, patented, and built two-shaft

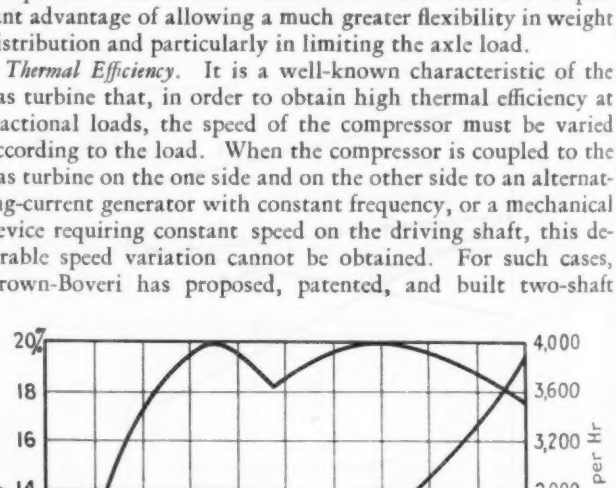


FIG. 9 EFFICIENCY AND FUEL CONSUMPTION FOR 5000-HP LOCOMOTIVE OF FIG. 2

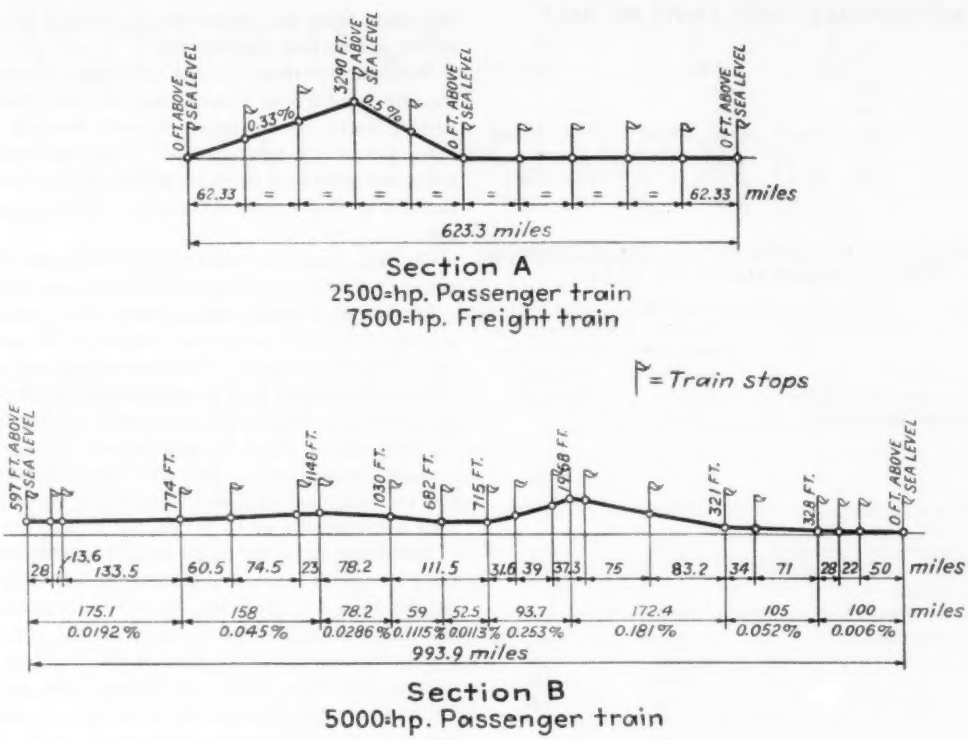


FIG. 10 TYPICAL PROFILES USED FOR COST ESTIMATES

arrangements comprising one gas turbine driving the air compressor only and allowing variable speed, and a second gas turbine, rated for the net power, which drives the generator or the mechanical device at constant speed. For a locomotive power plant with direct-current electrical transmission, this two-shaft arrangement is not necessary, since it is readily possible to vary the speed of the single-shaft set in accordance with the load.

Fig. 9 shows the thermal efficiency of the two separate power units of the 5000-hp locomotive, as shown in Fig. 2, when one unit carries all the load up to 2400 hp. In order to obtain this high efficiency at low loads, it is necessary to have each generator of the first unit supply power to two traction motors; when the second unit comes in to supply power above 2400 hp each generator will furnish current to only one traction motor. However, if the two-shaft single-unit 5000-hp turbine was used in Fig. 2, the controls would be as simple as the present 2500-hp unit, each generator feeding one motor.

On the other hand the two-shaft single-power-plant arrangement requires further controls for the gas turbines in addition to those of two separate complete power units, operated in parallel or singly as the service may require.

OPERATING AND MAINTENANCE COSTS

For the comparisons on operating and maintenance costs which follow, it was necessary to make a number of assumptions. The data on Diesel-electric locomotive performance were taken from many accounts published in this country at frequent intervals.

Based on prewar conditions, the average purchase price of Diesel-electric locomotives was $85 to $90 per hp. For a gas-turbine locomotive designed to satisfy American railroad practice, the weight and cost of the mechanical parts and the electrical equipment will be approximately the same as on a Diesel-electric locomotive for the same power and tractive effort. The gas-turbine power plant is lighter and will cost about 70 per cent of the Diesel engine. Hence an estimated purchase price for the gas turbine-electric locomotive of $76 to $81 per hp is entirely justified. This corresponds to 90 per cent of the cost of the Diesel-electric locomotive.

Interest on capital investment is assumed to be 4 per cent.

It is generally recognized that turbo-type machinery is subject to less wear and requires fewer replacement parts than reciprocating engines. It is therefore reasonable to assume a useful life of the gas-turbine locomotive of 20 years as against 15 years for the Diesel-electric locomotive. This results in annual depreciation charges of 5 per cent for the gas-turbine locomotive and $6^2/_3$ per cent for the Diesel locomotive.

In order properly to compare variable operating costs it is necessary to consider specific trains running over certain well-defined routes, comparable to the lines over which Diesel-electric trains operate in this country. The comparison is made for trains of the same total weight and locomotives with the same rating on the engine shaft.

Three different trains have been considered, operating over the lines shown in Fig. 10:

1 Passenger train of seven cars powered by a 2500-hp locomotive (end unit of Fig. 3) with a total weight of 755 tons. This train will make a round trip over section A, Fig. 10, in about 24 hours. On the assumption of 150 of these round trips per year the total distance covered will be about 187,000 miles.

2 Passenger train of 14 cars with 5000-hp locomotive (Fig. 2) and a total weight of 1470 tons. For a round trip over section B, Fig. 10, about $33^1/_2$ hr will be required. Assuming 120 round trips per year results in a total annual distance of about 239,000 miles.

3 Freight train with 7500-hp locomotive (Fig. 3) and a total weight of 5390 tons. Operating over section A this train will require about 36.3 hr for one round trip; 120 such round trips will result in a total annual mileage of 149,000 miles.

In establishing maintenance charges, published data on Diesel-electric trains have been used. For gas-turbine locomotives of approximately the same weight and axle arrangement the maintenance of the mechanical parts should be about the same as in Diesel locomotives. Also for the electrical equipment equal maintenance is assumed even though the lack of

TABLE 2 MAINTENANCE COSTS, CENTS PER MILE

Train	1		2		3	
Locomotive, hp	2500		5000		7500	
	Gas turbine	Diesel	Gas turbine	Diesel	Gas turbine	Diesel
Electrical equipment	2.0	2.0	3.3	3.3	5.5	5.5
Prime mover	3.21	5.6	6.0	11.1	10.0	18.0
Mechanical parts	3.4	3.4	5.47	5.47	12.5	12.5

TABLE 3 PASSENGER TRAIN 1, OPERATING OVER SECTION A; TOTAL MILEAGE 187,000 MILES PER YEAR

	Gas turbine-electric locomotive, 2500 hp	Diesel-electric locomotive, 2500 hp
Purchase price of locomotive	$191250	$212500
Saving with gas-turbine locomotive	21250	....
Annual Costs		
Fixed charges:		
Interest on capital, at 4 per cent	7650	8500
Depreciation:		
Gas-turbine locomotive, at 5 per cent	9562	—
Diesel-electric locomotive, at 6²/₃ per cent	—	14142
Operating costs, variable:		
Maintenance of electrical parts	3740	3740
Maintenance of thermal parts	6000	10472
Maintenance of mechanical parts	6358	6358
Fuel cost	15800	13360
Lubrication cost	753	2931
Total of annual expenses	$ 49863	$ 59503

TABLE 4 PASSENGER TRAIN 2, OPERATING OVER SECTION B; TOTAL MILEAGE 239,000 MILES PER YEAR

	Gas turbine-electric locomotive, 5000 hp	Diesel-electric locomotive, 5000 hp
Purchase price of locomotive	$382500	$425000
Saving with gas-turbine locomotive	42500	....
Annual Costs		
Fixed charges:		
Interest on capital, at 4 per cent	15300	17000
Depreciation:		
Gas-turbine locomotive, at 5 per cent	19125	
Diesel-electric locomotive, at 6²/₃ per cent		28305
Operating costs, variable:		
Maintenance of electrical parts	7887	7887
Maintenance of thermal parts	14340	26529
Maintenance of mechanical parts	13098	13098
Fuel cost	48000	38600
Lubrication cost	2000	7249
Total of annual expenses	$119750	$138668

TABLE 5 FREIGHT TRAIN 3, OPERATING OVER SECTION A; TOTAL MILEAGE 149,000 MILES PER YEAR

	Gas turbine-electric locomotive, 7500 hp	Diesel-electric locomotive, 7500 hp
Purchase price of locomotive	$563625	$626250
Saving with gas-turbine locomotive	62625	
Annual Costs		
Fixed charges:		
Interest on capital, at 4 per cent	22535	25050
Depreciation:		
Gas-turbine locomotive, at 5 per cent	28171	
Diesel-electric locomotive, at 6²/₃ per cent		41332
Operating costs, variable:		
Maintenance of electrical parts	8200	8200
Maintenance of thermal parts	14900	26820
Maintenance of mechanical parts	18625	18625
Fuel cost	97500	69000
Lubrication cost	3544	9180
Total of annual expenses	$193475	$198207

vibration from the prime mover should favor the machinery of the gas-turbine locomotive.

While as yet there are not sufficient records on maintenance for the gas-turbine power plant of the Swiss locomotive to permit final conclusions, Brown Boveri's experience over many years with large numbers of gas turbines in other applications indicates that these costs for a gas turbine will not be more than 54 to 58 per cent of those for a Diesel engine of equal output.

On this basis, the maintenance charges in cents per mile, given in Table 2, are believed to represent actual conditions.

For the fuel costs, the average price considered for Diesel oil was 4.5 cents per gal, for bunker C oil used on the gas turbine 2.7 cents per gal. This corresponds to a ratio of 5:3. In determining total fuel consumption for the several runs, 15 per cent was added to the estimated amount for the gas-turbine locomotives to allow for unexpected stops, slow-speed orders, no-load periods, etc. For the Diesel-electric locomotives, a fuel consumption of 0.41 lb per hp-hr was assumed and a no-load consumption of 12 per cent of this figure.

Published data on lubricating requirements of locomotive Diesel engines show consumptions between 0.025 and 0.055 gal per mile for the power range and service considered here. The lubrication costs for the electrical and mechanical parts are of the order of 5 per cent of the fuel costs. We can again assume the same costs in dollars—not percentage—for the mechanical and electrical parts of the gas-turbine locomotive. We must realize that the lubricating needs of the gas turbine itself are almost negligible, certainly not over 0.5 per cent of the fuel costs, as compared to the lubricating consumption of the Diesel engine itself, which is 10 to 15 per cent of the fuel costs.

The results of these computations are given in Tables 3 to 5, for the three trains considered, and show marked advantages especially for the gas-turbine locomotives on passenger trains. Further points in favor of the gas-turbine locomotives may be mentioned as follows:

1 No water requirements, except for train-heating boiler.
2 No reciprocating parts, thereby minimizing vibration.
3 Smaller number of power units for given output. Simplicity of control resulting from fewer units.

It will be observed that these results are obtainable with existing and tried gas-turbine designs for an inlet gas temperature of 1112 F, i.e., without awaiting future developments in alloys permitting higher temperatures. Naturally the economic advantages of the gas-turbine locomotive will become even more attractive when the metallurgists can provide alloys for continuous operation with higher inlet temperatures to the gas turbine. Such advances will have a very pronounced influence on the power developed by a given gas-turbine frame size, or in a given locomotive unit, or on the thermal efficiency of the power plant or both.

The result will be lower first costs and fixed charges, and, particularly, reduced fuel costs.

At some time, perhaps not too far distant, a continuous gas-inlet temperature of about 1380 F may be possible. The "standard" power plant on which these comments are based will then deliver 2500 hp at 28 per cent thermal efficiency or 3800 hp with 26.5 per cent thermal efficiency. This means that Fig. 2 will then have 7600 hp, all in one locomotive unit.

Even without this promise of "better things to come" in the somewhat distant future, it is believed that the gas-turbine locomotive shows sufficient merit today to warrant serious consideration by forward-looking railroad engineers. The Brown Boveri gas-turbine unit has outgrown the experimental stage. Brown Boveri is prepared to build locomotive power plants designed to satisfy American railroad requirements, with firm guarantees on performance, output, and thermal efficiency.

A GAS-TURBINE ROAD LOCOMOTIVE

By J. T. RETTALIATA

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IN considering the selection of motive power, the combustion-gas-turbine locomotive appears to have certain inherent advantages which would seem to justify its adoption. The present paper will outline some of these advantages, and details will be discussed of a proposed 4800-hp gas-turbine locomotive being studied by the author's company.

CONSIDERATIONS POINTING TO THE GAS-TURBINE LOCOMOTIVE

Since no water is required in its operation, the gas-turbine cycle should be particularly attractive for locomotive installations. Elimination of the now necessary water-treating provisions and frequent inspections, cleanings, and repairs of boilers used on present steam locomotives should certainly be desirable. Of additional importance would be the improved operating schedules possible on runs which formerly made stops for water.

The large amount of excess air used in the gas-turbine combustion process permits a clear stack completely free from smoke at all loads on the unit. The desirability of such a feature in view of some present city ordinances is manifest.

The purely rotary motion of the gas turbine will result in minimum maintenance and vibration. Absence of any reciprocation, with its concomitant unbalanced forces, is obviously beneficial. Since the elements of the gas turbine are similar to those of steam turbines, maintenance after development should be essentially of a moderate order, except for such additional work as might result from the higher temperatures employed. Operating experience with the Houdry turbines indicates very low maintenance for this equipment which operates at temperatures in the range of those employed in modern high-temperature central-station practice. Several of the oil-refinery gas turbines have demonstrated an exceptionally high order of reliability by operating continuously for as long as 2 years without shutdown.

Lubrication costs of the gas turbine, there being no sliding surfaces except for journal bearings, should not exceed 1 per cent of the fuel costs. It is understood that such costs on present railway equipment are substantially in excess of this figure.

It would undoubtedly be desirable to have a coal-burning gas-turbine locomotive but, notwithstanding the promising experiments with pulverized coal, there may be an appreciable time interval before this is realized. The inherent low heat release of coal, necessitating relatively large combustion-chamber volumes, when compared with liquid fuel, limits its consideration at present to stationary plants where space and weight are not at a premium as in mobile installations. Therefore, until apparatus having higher heat-release capacity is developed, it appears that liquid fuel will be used in locomotive applications. Colloidal fuels should also be given consideration, but in their present state high preparation costs somewhat lessen their attractiveness.

When dynamic braking is considered, the application of the gas turbine to locomotives is exemplary. By operating the traction motors as generators, the motorized main generators may be loaded by driving the gas turbine and its associated compressor. The energy required during compression can be dissipated by discharging the compressed air to the atmosphere. With such an arrangement, the electrical-resistor grids normally required for dynamic braking are eliminated.

The thermal efficiency of the gas turbine naturally will vary with the type of cycle employed. For locomotive service, where space limitations will have an important influence, certain refinements permissible in stationary plants will necessarily have to be omitted. Assuming a turbine-inlet temperature of 1200 F, the simplified basic cycle, comprising a compressor, a turbine (or two turbines arranged in parallel), and a combustion chamber, will yield a thermal efficiency at the shaft coupling of about 19 per cent. If a more elaborate cycle of the reheat type, employing a moderate amount of regeneration and operating with turbine inlet temperatures of 1200 F, is adopted, thermal efficiencies of 25 per cent are possible. With a hydromechanical type of transmission of 90 per cent efficiency, these thermal efficiencies when referred to the rail would become 17.1 and 22.5 per cent, respectively. With an electrical transmission having an efficiency of 83 per cent, the respective rail thermal efficiencies would be 15.8 and 20.8 per cent. When consideration is given to the low-grade fuel oil which it is capable of using, these efficiencies make the gas-turbine drive relatively attractive when compared with other types of locomotives on a fuel-cost basis.

In 1939, the author's company conducted an engineering study of the combustion-gas turbine as a locomotive drive. Consideration was given to four different gas-turbine locomotives including (*a*) a 5000-hp unit with hydromechanical transmission, driven by two separate power turbines, each connected to a main gas turbine - axial compressor set; (*b*) a 5000-hp unit with hydromechanical transmission, driven directly by two main gas turbine - axial compressor sets; (*c*) a 4500-hp unit with electrical transmission, driven directly by two main gas turbine - axial compressor - electric generator sets; and (*d*) a 2250-hp unit with electrical transmission, driven directly by a single main gas turbine - axial compressor - electric generator set. A heat exchanger was also incorporated in the latter design.

The results of this study led to the conclusion that the hydromechanical transmission, comprising reduction gear, torque converter, and hydraulic coupling, essentially duplicated the favorable performance characteristics of the electrical transmission and, in addition, had weight and efficiency advantages which made it appear as the most promising type of drive. Notwithstanding this decision, which is still believed to be justified and valid in every respect, the present paper deals with a locomotive design having electric drive.

The selection of the latter type of drive was not due to any inadequacies in the mechanical transmission, but rather to the fact that much operating experience has been acquired with the electrical type, and therefore advantage could be taken of its well-known characteristics, thereby permitting more intensified concentration on the development of the gas turbine itself. Furthermore, adoption of the electrical transmission appeared to be the most judicious procedure at this stage, since it would enable continued use to be made of certain established main-

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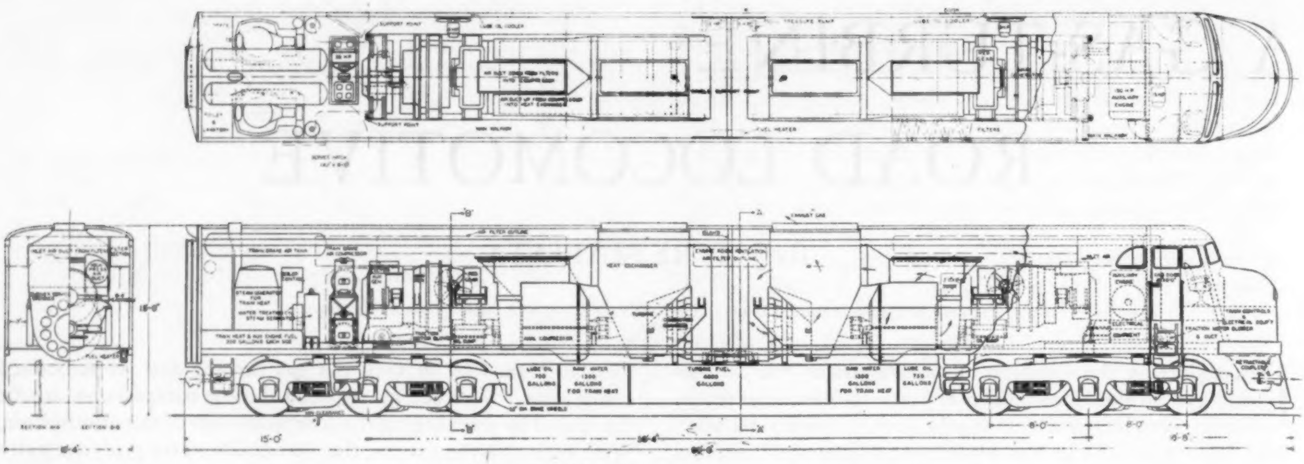


FIG. 1 ARRANGEMENT OF 4800-HP GAS TURBINE-ELECTRIC LOCOMOTIVE

tenance facilities, and because of the fact that the railroad personnel, being familiar with it, would be required to learn only that additional operating technique pertaining to the gas-turbine equipment. After the gas turbine has been proved to be a reliable and desirable type of railroad motive-power unit, it is believed that further developments should include the mechanical transmission in order to achieve the ultimate in locomotive design.

DESCRIPTION OF PROPOSED GAS-TURBINE LOCOMOTIVE

The road locomotive to be discussed in this paper is of 4800 hp capacity, being powered by two duplicate 2400-hp gas turbines each driving, through a reduction gear, direct-current main and auxiliary electric generators. The main generator is connected to traction motors furnishing power to the axles.

Fig. 1 shows a section through the proposed 4800-hp locomotive. The over-all length is 90 ft, and the distance between bolster centers is 58 ft 4 in. The two 3-axle trucks with 16-ft wheel base have 52-in-diam driving wheels, and each axle is powered by a nose-hung direct-current traction motor. When compared with conventional steam-locomotive wheel arrangements, it is expected that the two-truck design with provisions for proper lateral axle motion and the elimination of the reciprocating motion of pistons and side rods will result in reduced track maintenance.

The estimated weight of the locomotive is 450,000 lb with possibilities of reduction by employing lightweight materials. The wheel loading per inch of diameter therefore does not exceed accepted present practice. A 2400-hp gas-turbine power unit is arranged at each end of the locomotive cab, permitting the weight to be more uniformly distributed, with most of it directly over the trucks. For each power unit, the common frame carrying the turbine, compressor, reduction gear, and generators is supported at three points for the purpose of maintaining correct alignment. Two of the support points are located laterally directly over the center axle of each truck, while the third, in vertical line with the No. 1 turbine bearing, is on the center line and near the center of the cab.

The filters for the intake air to the gas turbine-compressor units are located on both sides of the cab near the top at each end. They are placed as high as feasible so as to reduce the possibility of disturbed foreign objects along the roadbed being inducted. Furthermore, the high intakes are desirable when the locomotive is standing in a station with engines running, where passengers may be in the vicinity.

The exhaust gases leaving the heat exchangers are discharged through the roof of the locomotive.

Two 2250 lb per hr steam generators are provided for train-heating. It is possible, with the gas-turbine type of drive, to install a waste-heat boiler in the exhaust passage beyond the heat exchanger and generate steam for heating purposes. However, in the interest of simplicity, it was decided to forego such a refinement on an initial gas-turbine installation, and therefore only the conventional type of boilers is indicated. After a sufficient accumulation of operating experience has proved the merit of the gas turbine itself, it would in all probability be expedient to incorporate in future locomotive designs a waste-heat means of generating heating steam also.

An auxiliary engine generator set of 150 hp is provided for starting the two gas-turbine power plants by motorizing the main generators. One of the numerous advantages of having two smaller power units instead of a single larger one of the same aggregate output is apparent in this instance, since it permits smaller-capacity starting equipment to be employed. By connecting the auxiliary set directly to the traction motors, it may also be used for propelling the locomotive up to speeds of approximately 15 mph, thus enabling the main units to remain shut down when it is desired to move the locomotive about the yards.

Since the use of a relatively heavy low-grade fuel is contemplated, provision is made for fuel-heating. There are various methods of accomplishing this, either with steam or electrical heating, but probably the most logical would be to use the exhaust gas from the turbines. For starting purposes the light auxiliary-engine fuel, requiring no preheating, could be used temporarily in the combustion chambers of a main power unit until the flow of exhaust gas is established.

In the space under the center of the cab between the two trucks, tank capacity is provided for 4000 gal of turbine fuel oil, 1500 gal of lubricating oil, and 2600 gal of water for train-heating. The fuel-oil capacity is sufficient for approximately a 10-hr run. Two 300-gal tanks in the rear of the cab contain fuel for the auxiliary engine and the steam generators.

No water is required for the gas-turbine power plants themselves, as all cooling is done with air; two fan coolers being used for the lubricating oil, and blowers for cooling the generators and traction motors.

Train controls and associated electrical equipment are in the forward end of the locomotive.

After development is completed, it is estimated that the expected cost of the locomotive will be approximately 75 to 85 dollars per horsepower.

GAS-TURBINE POWER PLANT

A section through one of the duplicate gas-turbine power units is shown in Fig. 2. A 5-stage reaction-type gas turbine *A* drives a 22-stage axial compressor *B*. Filtered air from the atmosphere traverses the compressor where its pressure is increased. It next passes through the crossflow heat exchanger *C*, where its temperature is raised by the turbine exhaust gas.

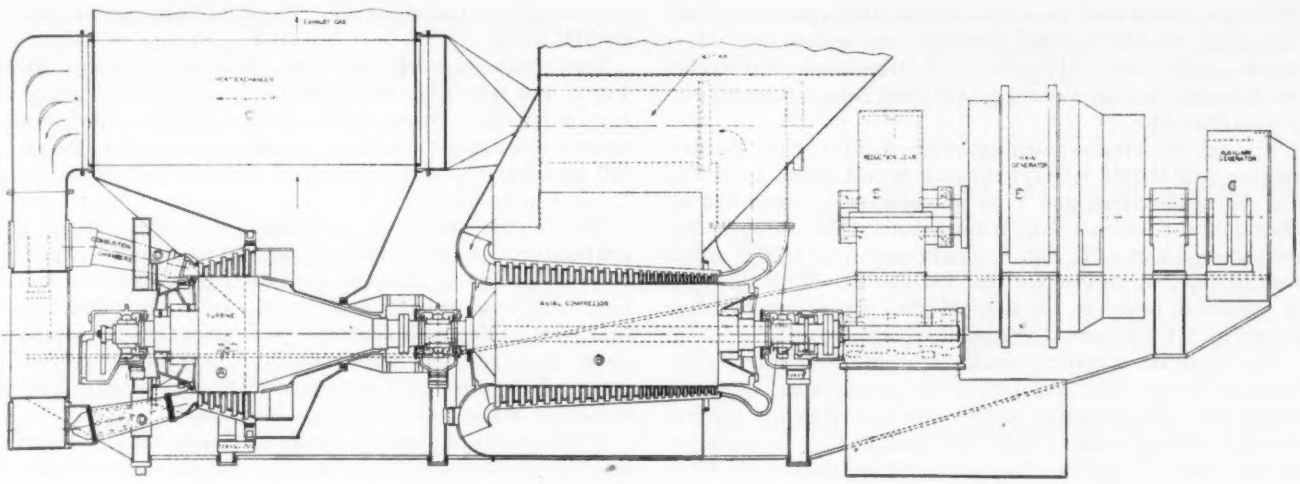


FIG. 2 ARRANGEMENT OF 2400-HP GAS-TURBINE POWER PLANT

The heated air then flows in parallel through a group of twelve separate combustion chambers *D*, ahead of the turbine. Part of the air is used for combustion purposes in an inner shell, while that remaining flows through the annular space between the inner and outer shells and cools the products of combustion to a satisfactory turbine inlet temperature. A series of smaller combustion chambers is used instead of a single large one, as it has been found that in certain instances more satisfactory combustion at higher heat release can be obtained in this manner. The gas, a mixture of air and combustion products, then expands through the turbine from which it is exhausted to the atmosphere through the heat exchanger where it preheats the air from the compressor. The power developed by the turbine is greater than that required by the compressor and the excess power is supplied through the reduction gear *E* to the main generator *F* and the auxiliary generator *G*.

In order to start the unit from a standstill, the generator is switched from shunt to series field and motorized by an auxiliary engine generator set, bringing the unit up to about 30 per cent of maximum operating speed, at which point the turbine, at full gas temperature, is capable of driving the unit by itself. The full-load speed of the turbine and compressor is 5000 rpm and that of the generators is 900 rpm. The turbine and compressor, supported on a common frame with the gear and generators, are arranged as a three-bearing unit.

The gas turbine is designed for a maximum continuous operating temperature of 1200 F. The thermal efficiency of a gas-turbine cycle improves with increase in turbine inlet gas temperature, and therefore it is desirable to use as high a temperature as is consistent with mechanical reliability. In the present state of gas-turbine development, it is believed that 1200 F is the maximum temperature which should be adopted for prime-mover-type power plants where continuous operation with reliability is a basic requirement.

The proposed locomotive-gas-turbine element is in general similar to that of Fig. 3, which shows one of the turbines used in the Houdry oil-refinery units. Its associated axial compressor, shown in Fig. 4, is also of the type employed in the locomotive unit. Thus the basic turbine and compressor designs resemble very closely those which have performed so reliably in oil-refinery service.

The crossflow, tubular-type heat exchanger has a surface of 1.4 sq ft per useful horsepower output of the gas-turbine power plant. The effectiveness of the heat exchanger is 50 per cent.

GAS-TURBINE CHARACTERISTICS

The thermal efficiency obtainable with the gas-turbine locomotive will depend upon the mode of operation adopted. If high thermal efficiency were the only consideration, then maximum turbine-inlet temperature should be maintained at all loads. The variation of coupling thermal efficiency with output of one of the 2400-hp gas-turbine power plants would then be as shown by curve *ADE* in Fig. 5. The temperature characteristic would be as indicated by curve *ADE* in Fig. 6. Operation of this sort would necessitate a proportional reduction in the rotative speed of the prime mover as the load diminished. Curve *ADE* of Fig. 7 shows that the speed would vary from

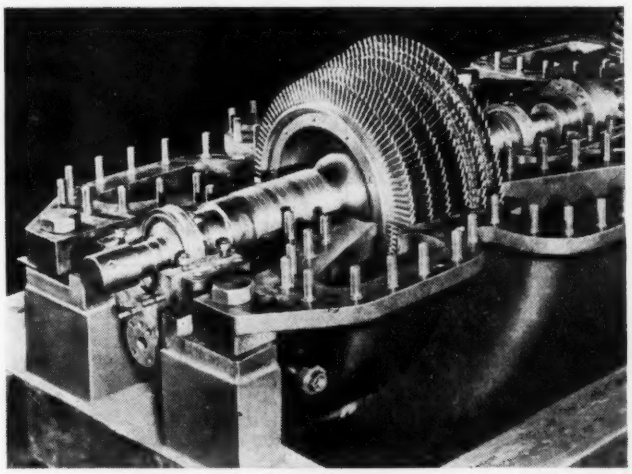


FIG. 3 GAS TURBINE WITH TOP CASING REMOVED

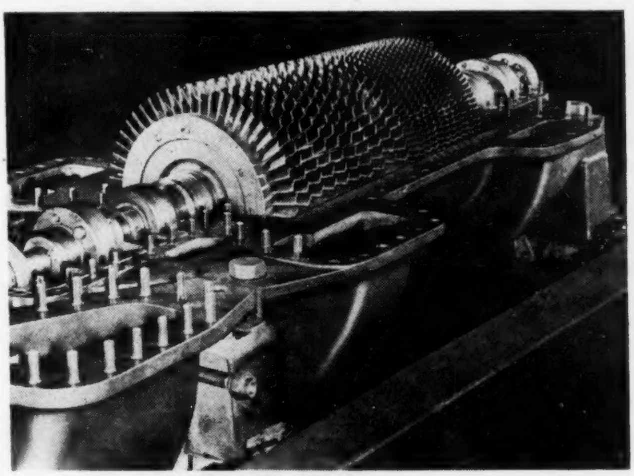


FIG. 4 AXIAL COMPRESSOR WITH TOP CASING REMOVED

5000 rpm at full load to approximately 1500 rpm at no load. Decreased rotative speeds, however, are undesirable where rapid response is needed because of the time required to accelerate the rotating masses of the power plant before increased output is obtained.

If rapid acceleration were the prime requisite then the gas-turbine unit should be kept running at full speed, curve *CE*, Fig. 7, at all times, and variation in load accomplished by changing the turbine inlet temperature. The turbine inlet temperature, curve *CE*, Fig. 6, would vary from 1200 F at full load to 740 F at no load for such conditions. With this type of operation, however, the thermal efficiency, shown by curve *CE* in Fig. 5, is substantially reduced at partial loads.

The optimum operating condition would be a compromise between curves *ADE* and *CE*. Such performance, as determined both by acceptable acceleration and efficiency requirements, is shown by curve *BDE*, Figs. 5, 6, and 7. In establishing the mode of operation for this condition, the minimum rotative speed was limited to 60 per cent of normal. This was adopted to assure reasonable acceleration characteristics, and also to prevent the possibility of "pumping" of the axial compressor as such a tendency may exist at speeds lower than the minimum selected when the turbine inlet temperature is increased to meet load demands. The speed-load curve is shown by *BDE* in Fig. 7.

The temperature characteristic, depicted by curve *BDE*, Fig. 6, was selected so as to maintain the thermal efficiency as high as possible over most of the load range. Accordingly, the temperature has the maximum continuous value of 1200 F from full load down to approximately 32 per cent load, diminishing to 600 F at no load.

The thermal efficiency associated with these speed and temperature characteristics is shown as a function of output by curve *BDE*, Fig. 5. From no load to 32 per cent of rated output, it can be seen that the efficiency is appreciably better than that obtainable with constant-speed operation but slightly under that possible with constant temperature. At loads greater than 32 per cent, the efficiency procurable with 1200 F maximum continuous temperature is realized.

It will be noted that in the three different modes of operation mentioned the thermal efficiency at rated output is the same for all cases, namely, 20 per cent at the shaft coupling. Below the rated load, the efficiency depends upon the type of operation selected.

GOVERNING CHARACTERISTICS OF GAS-TURBINE POWER PLANT

Having chosen as most desirable the type of operation represented by curves *BDE* of Figs. 5, 6, and 7, showing, respectively, thermal efficiency, turbine inlet temperature, and rotative speed as a function of output, a method of governing possessing performance characteristics suitable for railway application must next be determined. Requirements of a good governing system are primarily the maintenance of high thermal efficiency in conjunction with beneficial acceleration characteristics. There are various ways whereby gas-turbine power plants could be controlled, and three different types will be described. The thermal efficiency under balanced load conditions will be as given by curve *BDE*, Fig. 5 and will be the

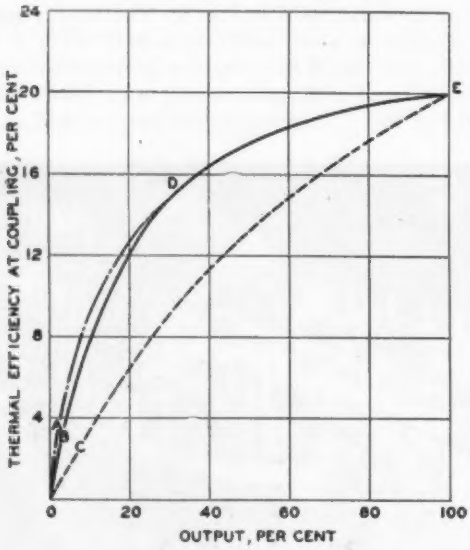


FIG. 5 THERMAL EFFICIENCY

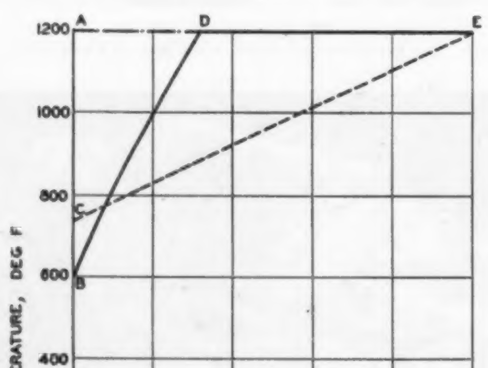


FIG. 6 TURBINE INLET TEMPERATURE

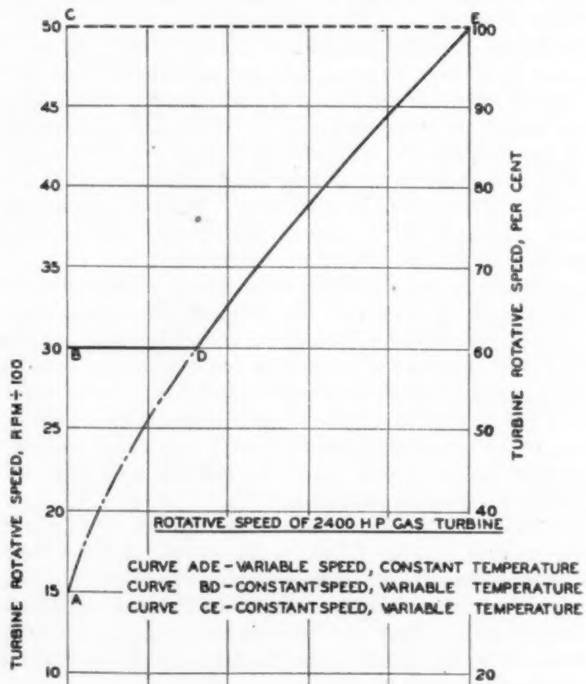


FIG. 7 TURBINE ROTATIVE SPEED

same for all types, the difference between the control methods being in the rate of acceleration.

For purposes of illustration, in each case let it be assumed that the power plant is operating at point *D* of Figs. 5, 6, and 7, and it is desired to accelerate from this point. While the maximum turbine inlet temperature has been stated to be 1200 F, a temperature of 1300 F will be used during periods of acceleration, since the time interval is of such limited duration that no deleterious effect should result.

Accordingly, one method of control, upon movement of the throttle in the direction of increasing speed could, under maximum accelerating conditions, immediately increase the temperature to 1300 F, while simultaneously raising the output of the power plant in accordance with a predetermined condition. For instance, by means of adjusting the generator field the output for traction purposes could be maintained in accordance with curve *DE*, Fig. 7, as the turbine rotative speed increased. Consequently, since curve *DE* is based upon a constant turbine inlet temperature of 1200 F, the additional energy available with 1300 F goes into accelerating the rotative masses of the power plant. With such a governing arrangement, it would require approximately 45 sec to increase the rotative speed of the power plant from 60 per cent (point *D*, 32 per cent load) to 100 per cent (point *E*, 100 per cent load).

A second type of control system could be somewhat similar to the foregoing, except that instead of keeping an external load on the power plant, as defined by curve *DE*, the load would, at the initiation of acceleration when the temperature is increased to 1300 F, be held at a constant value, represented by point *D*, until full speed of the gas-turbine unit had been attained. Thus the output supplied to the traction motors during the prime-mover accelerating period would remain fixed, while the difference between the increasing energy corresponding to a turbine-inlet temperature of 1300 F and the energy existing at point *D* would be utilized in raising the rotative speed of the power plant up to its full value. Regulation of this sort would consume approximately 18 sec before the rated speed of rotation was attained.

A third and still more rapid method of acceleration would comprise, at the start of acceleration, increasing the temperature to 1300 F and simultaneously removing the external connected load from the power plant. This type of control would require the least accelerating time since the entire gas-turbine output at 1300 F would be devoted exclusively to accelerating the prime mover itself. In this instance the actual elapsed time before rated load would be available to the locomotive would be approximately 8 sec.

Assuming the third method, or variations of it, to be preferable because of its advantageous acceleration characteristics, the means for accomplishing the desired governing could function as follows: To produce an increase in speed an advancement of the throttle would (*a*) introduce more fuel into the combustion chamber, a thermostatic device, however, limiting the fuel so that the maximum temperature at the turbine inlet would not exceed 1300 F; (*b*) reduce the generator field so as to remove load from the prime mover; and (*c*) reset the turbine speed governor by compressing its spring and thereby move the governor weights closer to the vertical axis of rotation. As the rotative speed of the power plant increased up to its full value, the changing position of the governor sleeve would increase the generator field and reapply external load.

LOCOMOTIVE PERFORMANCE CHARACTERISTICS

The available tractive-effort and rail-horsepower characteristics of the gas-turbine locomotive are shown as a function of train speed in Fig. 8, by curves *A* and *B*, respectively. The tangent level-track resistance of the 225-ton locomotive, when pulling cars weighing 1000 tons, is given by curve *C*. This curve was calculated on the assumption that the locomotive was hauling 15 cars. The intersection of the tractive-effort

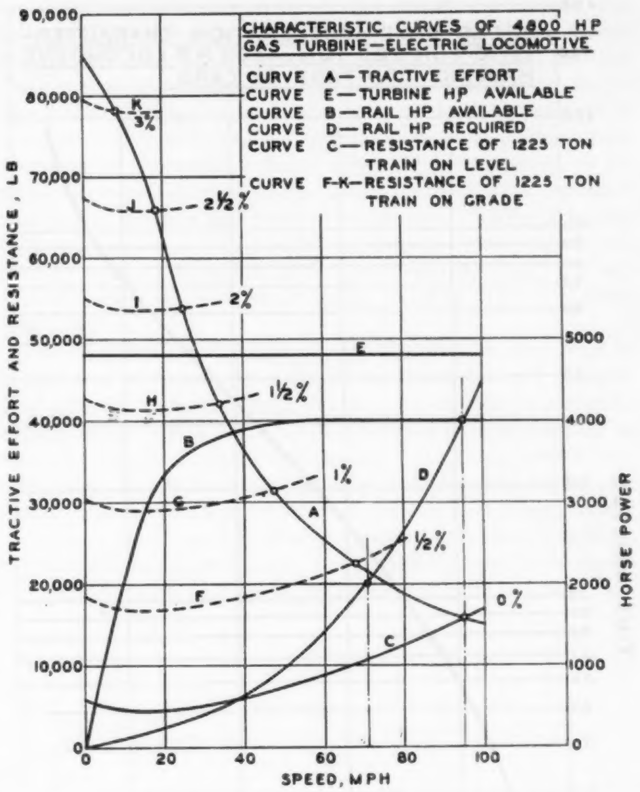


FIG. 8 CHARACTERISTIC CURVES OF GAS-TURBINE LOCOMOTIVE

and resistance curves shows that the 1225-ton train will have a top speed of 95 mph when traveling on level ground. The starting tractive effort of 85,000 lb is within the limit of adhesion, assuming a coefficient of static friction of 0.25 for the 225-ton locomotive.

The variation with speed of the rail horsepower required by the train is represented by curve *D*. The maximum speed of 95 mph may also be obtained from the intersection of curves *B* and *D*. With only one gas-turbine power unit in operation, the maximum power at the rail is 2000 hp, which, referring to curve *D*, is capable of producing a speed of approximately 70 mph.

Curve *E* shows the power available at the gas-turbine coupling with both power plants in operation, amounting to 4800 hp at all train speeds. Except in the very low speed range, where limitations in traction motor current may prevent full utilization of the available turbine outputs, the difference between curves *E* and *B* is attributable to the transmission losses and the power required to drive auxiliaries.

Curves *F* to *K*, inclusive, represent, at $^1/_2$ per cent intervals, the resistance of the 1225-ton train when negotiating grades from $^1/_2$ to 3 per cent, respectively. The intersection of the tractive-effort curve *A* with the various grade-resistance curves will give the maximum speeds at which the train can traverse the respective grades.

The speed-time acceleration characteristic for the 225-ton 4800-hp locomotive, when hauling 1000 tons of cars on a tangent level track, is shown on semilog co-ordinates in Fig. 9. The time required to attain a given speed may be obtained by successive summation using the basic relation

$$\Delta t = \frac{m}{f} \int dv$$

which may be put in the form

$$\Delta t = \frac{2050}{f} (v_2 - v_1)$$

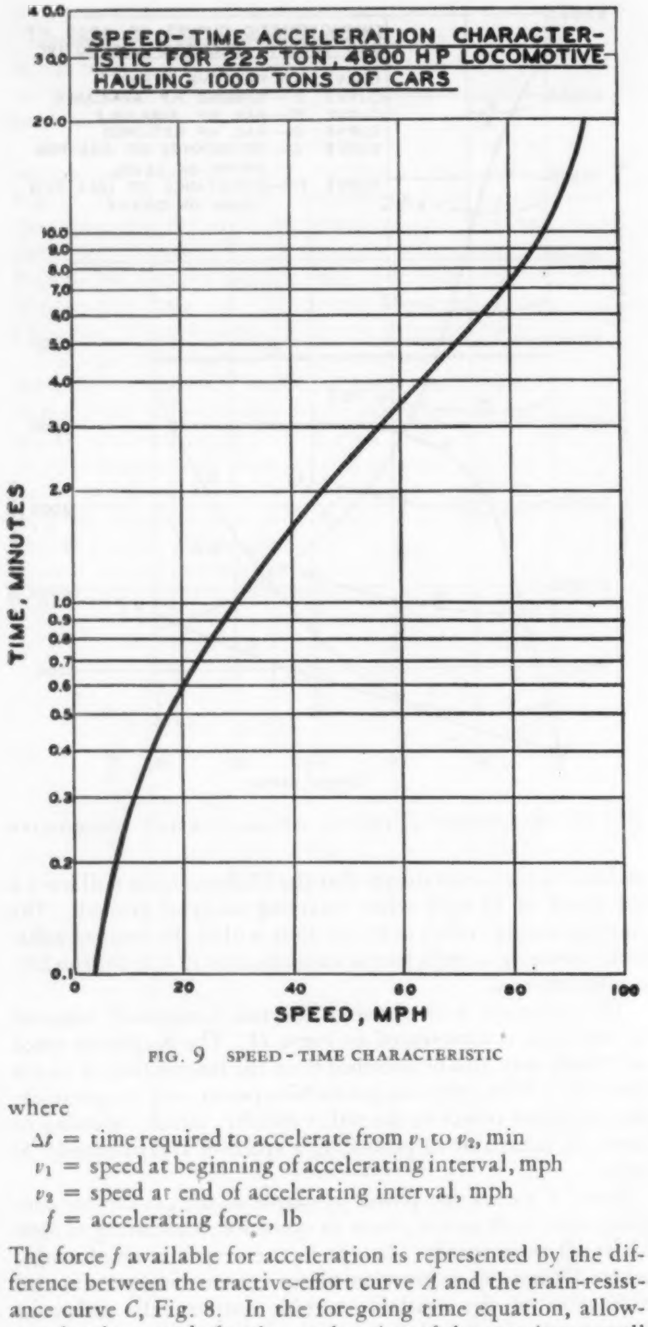


FIG. 9 SPEED-TIME CHARACTERISTIC

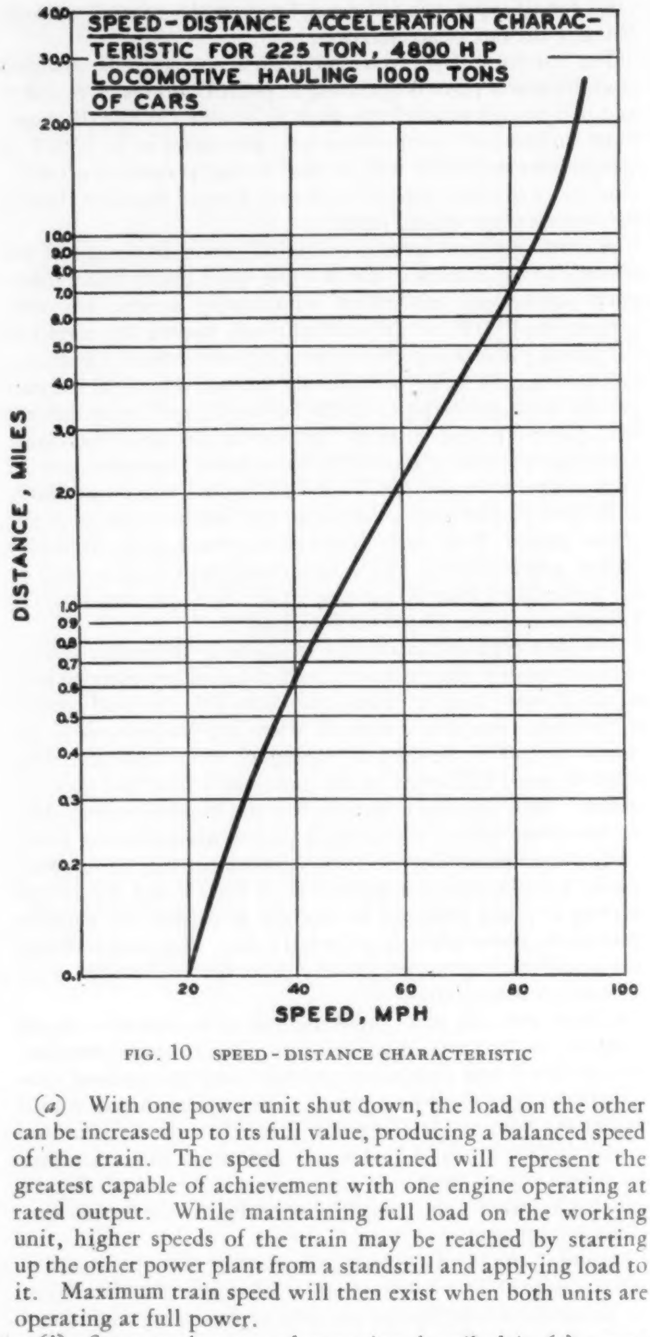


FIG. 10 SPEED-DISTANCE CHARACTERISTIC

where

Δt = time required to accelerate from v_1 to v_2, min
v_1 = speed at beginning of accelerating interval, mph
v_2 = speed at end of accelerating interval, mph
f = accelerating force, lb

The force f available for acceleration is represented by the difference between the tractive-effort curve A and the train-resistance curve C, Fig. 8. In the foregoing time equation, allowance has been made for the acceleration of the rotating as well as the translational masses of the train.

The tangent level-track speed-distance acceleration curve for the 1225-ton train is plotted on semilog co-ordinates in Fig. 10. In establishing this curve, the distance required to accomplish the acceleration in a given time interval can be calculated from

$$\Delta s = \frac{m}{f} \int v dv$$

which may be transformed into the more convenient form of

$$\Delta s = \frac{17.1}{f} (v_2^2 - v_1^2)$$

where Δs is the distance, in feet, during which the acceleration from v_1 to v_2 is accomplished. The other terms in the equation are the same as previously defined.

For a gas-turbine locomotive, having two duplicate power plants, several general methods of operation are possible. These may be stated as follows:

(*a*) With one power unit shut down, the load on the other can be increased up to its full value, producing a balanced speed of the train. The speed thus attained will represent the greatest capable of achievement with one engine operating at rated output. While maintaining full load on the working unit, higher speeds of the train may be reached by starting up the other power plant from a standstill and applying load to it. Maximum train speed will then exist when both units are operating at full power.

(*b*) Same as the type of operation described in (*a*) except that instead of the second power unit being shut down completely, it is kept running at all times, idling until the first unit is fully loaded, at which point it is brought in for producing higher speeds.

(*c*) Both units are operated simultaneously and carry equal loads at all times.

(*d*) Similar to type of operation described in (*c*), except that the load may be varied between the two power plants.

The various over-all thermal efficiencies of the 4800-hp gas turbine-electric locomotive referred to the rail for these different types of operation are shown in Fig. 11. Curve *ABDE* shows the variation in efficiency as a function of train speed which would occur if type (*a*) operation were adopted. As was shown in Fig. 8, a single 2400-hp unit is capable of driving the 225-ton locomotive, plus a 1000-ton train of cars at approximately 70 mph. Therefore, portion *AB* of the curve represents the efficiency with one unit operating and the other shut down. To obtain greater speeds, the second 2400-hp gas turbine is started up and brought in causing at first a sudden decrease in

over-all thermal efficiency to *D* at the transition point owing to its no-load idling fuel requirements. As additional power is extracted, the efficiency increases until it attains a maximum value at *E* corresponding to full speed of the train.

The thermal-efficiency characteristic which would exist for operating conditions (*b*), (*c*), or (*d*) is represented by curve *CDE*, Fig. 11. Notwithstanding the different conditions of these three types of operation, for all practical purposes they will have the same efficiency curve as indicated. For speeds up to 70 mph, curve *AB* is higher than *CD* because under type (*a*) operation, the absence of idling fuel requirements results in a greater efficiency than for type (*b*); and the running of the single power unit at a higher proportional rating at a given train speed results in more economical performance than is obtainable with types (*c*) and (*d*).

It would be possible to improve the efficiency of type (*b*) operation if the unloaded unit were idled at the minimum speed possible, approximately 30 per cent, instead of at 60 per cent which was adopted for reasons of acceleration. On this basis the thermal efficiency up to the transition point would lie about midway between curves *AB* and *CD*. In anticipation of passing through the transition point, the second unit could be brought up to proper speed in ample time.

Reference to Fig. 11 reveals the obvious desirability of employing operation of type (*a*). It is appreciated that opportunities for utilizing this kind of operation may not be too abundant but it should be possible where the character of the roadway, such as numerous curves, etc., prohibits the attainment of speeds in excess of 70 mph for reasonably long periods of time. Where the 70-mph speed point is passed through at fairly frequent intervals, it may be more convenient to adopt one of the other operating conditions as given by (*b*), (*c*), or (*d*), so as to eliminate the necessity of frequent starting and stopping of the second power unit. It is desired to emphasize the fact, however, that the favorable efficiency characteristic associated with type (*a*) operation is always available for realization even though conditions may be such as to prevent advantage being taken of it at all times.

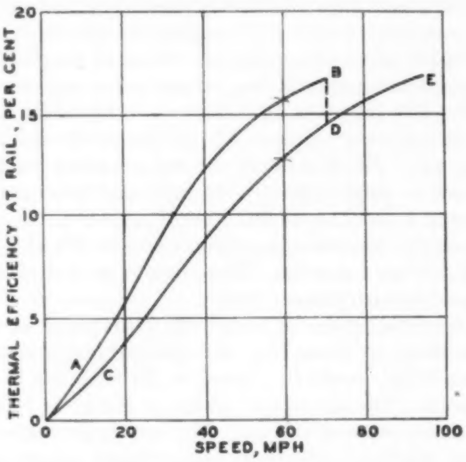


FIG. 11 THERMAL EFFICIENCY AT RAIL

Incidently, curve *CDE* is also indicative of the variation of efficiency with speed for a locomotive having a single power plant of the same capacity as the total of the two separate units, namely 4800 hp. This is based upon the assumption that the change in efficiency with load of the small and large units is the same which is not quite the case since the maximum thermal efficiency of the larger unit would be slightly higher because of the benefits of reduced leakage, etc.

The more favorable dimensional characteristics of the smaller units are significant. Assuming geometrical similarity, the larger unit will have a diameter 41 per cent greater than that of one of the half-size machines. Obviously, such a dimensional increase complicates the design and makes the installation problem more critical. Furthermore, the large power plant would have a specific weight per unit output 41 per cent greater than the two-unit scheme, thus necessitating larger wheel sizes in order to maintain the same loading per inch of diameter. If it were desired to retain the same diametral dimensions as the smaller units, it would be necessary to increase the rotative speed of the larger machine with concomitant higher stresses and reduced reliability. While it is true that strict adherence to the law of dynamic similitude is not entirely possible owing to certain incidental factors, it is sufficiently close, however, to assure the validity of the foregoing reasoning.

The two-unit arrangement is also desirable in the event of breakdown of one of the units, as the train can still be operated up to 70 mph on a single engine. Servicing of the double-engine design would probably be simplified in that it would be easier to remove a smaller lighter unit through the roof of the cab and replace it with a previously reconditioned engine and thereby have the locomotive in operation in minimum time.

In Figs. 12, 13, and 14, curve *ABDE*, as previously defined, represents type (*a*) operation; and curve *CDE* applies to operating conditions (*b*), (*c*), or (*d*), whichever may be selected.

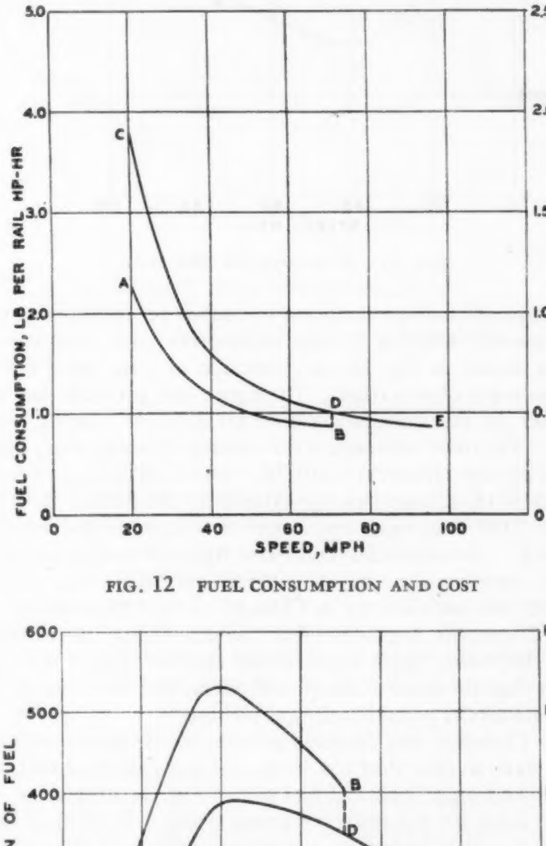


FIG. 12 FUEL CONSUMPTION AND COST

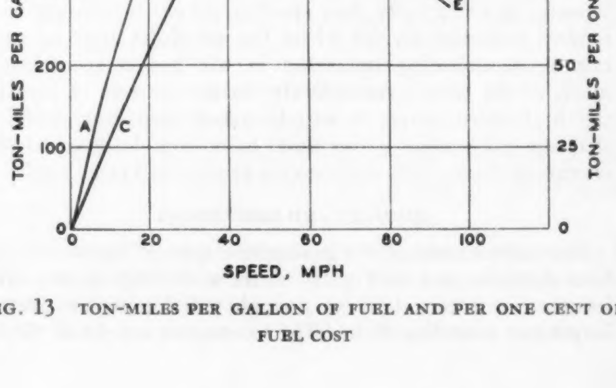


FIG. 13 TON-MILES PER GALLON OF FUEL AND PER ONE CENT OF FUEL COST

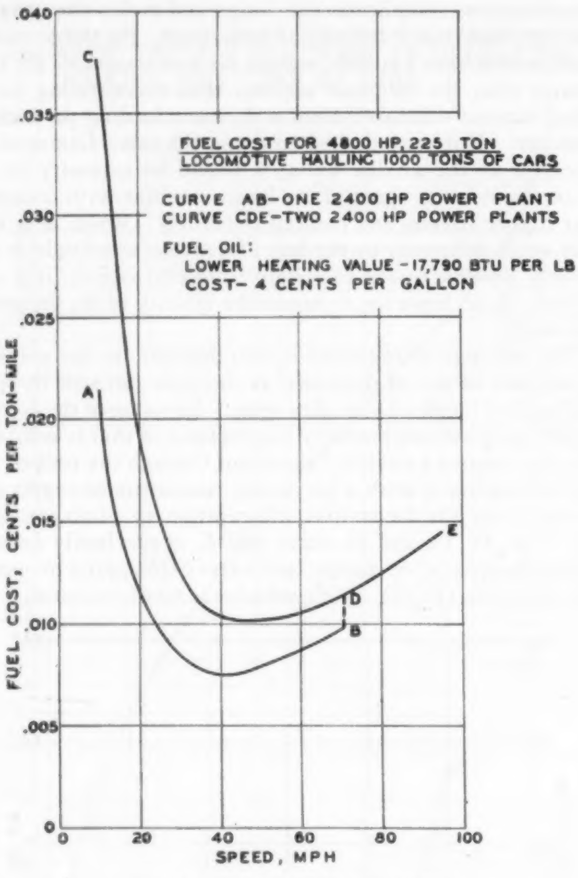


FIG. 14 FUEL COST PER TON-MILE

The specific fuel consumption in pounds per rail horsepower-hour for the 4800-hp 225-ton locomotive with 1000 tons of cars is shown in Fig. 12, as a function of train speed for the various types of operation. The figure also gives the fuel cost in cents per rail horsepower-hour for different running conditions. The more economical performance with type (*a*) operation is apparent from curve *ABDE*. A fuel oil having an A.P.I. gravity of 16, a lower heating value of 17,790 Btu per lb, a density of 7.998 lb per gal, and a cost of 4 cents per gal has been assumed. The selected average-cost figure of 4 cents per gal is on the conservative side since prices quoted on this type of fuel oil indicate the cost in Chicago to be 4.55 cents per gal and 2.28 cents in Argentine, Kan., in the vicinity of the wells. Thus the 4-cent figure is considered equitable, since it is even higher than the mean of the quoted prices, and therefore should not yield results partial to the gas turbine.

Fig. 13 shows, as a function of train speed, the ton-miles of gross train weight that can be hauled per gallon of fuel, and the ton-miles per 1 cent of fuel cost. Fig. 14 shows the fuel cost in cents per ton-mile at various speeds. In both of these figures it will be seen that, regardless of the type of operation selected, the optimum train speed occurs around 40 mph. Obviously, this relatively slow speed could not be adhered to in modern passenger service where fast schedules must be maintained, necessitating operation in the higher speed ranges much of the time. Accordingly, in the interest of favoring the high-speed range, it will be noted from Figs. 5 and 11 that the gas-turbine power units have been designed so that maximum thermal efficiency occurs at their full rated load.

SUMMARY AND CONCLUSIONS

The compactness of the gas-turbine type of locomotive has been demonstrated in Fig. 1, where a 4800-hp electric-drive locomotive is contained in a single cab having an over-all length not exceeding 90 ft. The locomotive weight of 450,000 lb is approximately one half that of some other types of modern locomotives of corresponding horsepower. The wheel arrangement comprises two six-wheel trucks with each axle motored. The two duplicate 2400-hp gas-turbine units which power the locomotive are believed to be preferable to a single unit of the same aggregate capacity since, assuming geometrical similarity, the larger unit would have both a specific weight per unit output and dimensions each 41 per cent greater than those of the smaller engines.

The 4800-hp locomotive, when hauling 15 cars weighing 1000 tons, will have a top speed at full output of 95 mph on a tangent level track. Its maximum speed with a single engine in operation would be approximately 70 mph. The acceleration characteristics show that on a tangent level track the train will attain a speed of 90 mph from a standstill in approximately 13 min and in a distance of about 15 miles.

The gas turbines are designed for a continuous maximum operating temperature at the turbine inlet of 1200 F with a permissible increase to 1300 F during the short engine acceleration periods. In order to minimize the time interval during such periods, the governing system could be arranged to reduce automatically the external load on the turbine unit at the initiation of the train acceleration period so that maximum energy can be applied to increasing the rotative speed of the prime mover itself in the shortest possible time.

The maximum efficiency of the locomotive referred to the rail is 16.8 per cent occurring at full output of the power plants. The corresponding specific fuel consumption and cost are, respectively, 0.86 lb, and 0.43 cents per rail hp-hr for a fuel having a lower heating value of 17,790 Btu per lb and costing 4 cents per gal. The maximum ton-miles hauled per gallon of fuel occurs at approximately 40 mph and amounts to 530, representing a fuel cost of 0.0076 cent per ton-mile. At maximum speed the ton-mile per gallon figure is 275 at a fuel cost of 0.0146 cent per ton-mile. These figures are believed to compare favorably with present practice.

In the foregoing material contained in this paper, an endeavor has been made to show that the gas turbine possesses characteristics which could be classed as desirable for locomotive applications. The absence of water in the cycle is a natural advantage for railway service. The low maintenance records associated with the oil-refinery gas turbines of similar design encourage the prescient contemplation that the service charges on locomotive units will be correspondingly moderate. As is characteristic with all equipment of turbine type, the lubrication costs should be exceedingly small and it is estimated that they will be less than 1 per cent of the fuel costs. While it is not possible as yet to use coal as a fuel in gas turbines, experiments along such lines are continuing but liquid fuels will probably be employed for a considerable period. Owing to the large percentages of excess air used in combustion, the exhaust gases will be absolutely clear and free from smoke at all times which is quite desirable. The incentives for the use of dynamic braking are enhanced still further in the case of a gas-turbine locomotive since the energy of retardation can be absorbed in the prime mover itself thereby making electrical resistors unnecessary. If electric train heating is desired the gas turbine admirably lends itself since the output increases with lowered atmospheric temperatures.

It is believed that adequate evidence has been presented to conclude with reasonable certainty that the gas turbine possesses sufficient natural advantages to assure it a place of recognition for locomotive applications.

ACKNOWLEDGMENT

It is desired to take this opportunity to acknowledge the invaluable assistance rendered by the Allis-Chalmers Manufacturing Company, and in particular by Messrs. R. C. Allen, J. L. Ray, J. A. Johnson, and C. E. Kenney in the preparation of this paper.

A Lightweight FLOOR *for* AIRPLANES

Type Adaptable for General Transportation Use

By JAMES R. FITZPATRICK

DIRECTOR, TECHNICAL PLY-WOODS, CHICAGO, ILL.

THE results of the work of aircraft engineers in keeping weight to a minimum will encourage engineers in every form of transport to travel a similar path. Lightweight means lower cost of transport of any type.

The scarcity of lightweight metals as a result of war demands called for a substitute. Plywood as made today met the requirements. Modern plastic-bonded plywood has done a good job; it has performed its function so well that it can hardly be called a substitute any longer. It is an accepted fact that, weight for weight, plywood is the strongest material known. Turning to plywood, the aircraft engineers found many applications for its use both in flat and in molded form.

Naturally, when a lightweight floor was sought, plywood was considered; not necessarily in its usual form, but a plywood that would provide the required strength and at the same time offer a greater saving in weight. Any saving per square foot results in substantial weight conservation.

The result was the introduction of hollow-core plywood of various designs. Usually the panels were of small size. The hollow cores were of different construction and different materials. Sometimes all cores were parallel strips several inches apart; in other cases they were of lattice or egg-crate construction. Materials used were spruce, pine, basswood, or balsa.

CHARACTERISTICS

Flooring of different construction and sizes had been furnished for about 2000 large bomber, cargo, and transport planes before an attempt was made to develop a floor with the following characteristics:

1 The flooring shall be able to withstand a concentrated load across the face of 500 lb with a deflection of not more than $^1/_4$ in. when the span is 18$^1/_2$ in.

2 The flooring shall be able to withstand, without puncturing, a load of 300 lb applied to an area of 1 sq in. (1 in. × 1 in.) anywhere on its surface and with a deflection not greater than $^1/_4$ in. This test was designed to simulate the heel of a woman's shoe.

3 The flooring shall be capable of withstanding the shock load of a 50-lb bag of lead shot dropped freely on the center of the panel rigidly supported at the edges, from a height of 8 in. above the floor surface. The shot bag shall be cylindrical and 6 in. diam.

4 The flooring shall have a thickness between $^5/_8$ and $^3/_4$ in.

5 The average weight of the floor shall not exceed 80 lb per 100 sq ft.

6 The floor is to be designed so that wherever it is necessary to attach fasteners or hold-downs of any type it is to have a solid-core construction.

7 The floor is to be designed so that it will have dielectric qualities.

8 The floor is to be furnished not in many small sizes, but in two large units, each panel to be 4 ft in width and 25 ft in length.

Contributed by the Wood Industries Division of The American Society of Mechanical Engineers.

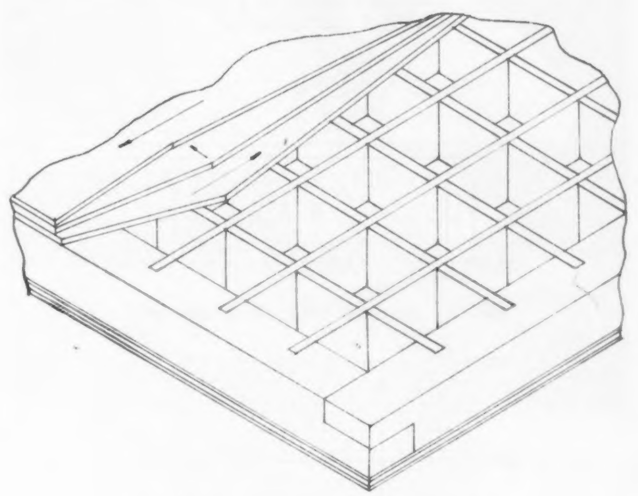


FIG. 1 HOLLO-CORE FLOOR PANEL

DEVELOPMENT OF HOLLOW-CORE PANELS

In order to conform to these requirements, a special type of hollow-core panel with plywood faces was developed, consisting of birch throughout with a core in which the rails and grid are airplane spruce throughout. The panels were made with phenolic-resin glue, hot-plate process, and were also applied to the core with phenolic glue.

A cross section of the panel showing the construction of grid, rails, and faces is shown in Fig. 1.

The original tests on sample panels were conducted by Prof. Howard J. Hansen, Agricultural and Mechanical College of Texas.

The description and results of his tests follow:

Description of Specimens:

Panel A: 24 in. × 12 in. × 0.778 in., with $^1/_{16}$-in. 3-ply birch face, and $^3/_{64}$-in. 3-ply birch back; spruce core. Weight, 0.83 lb per sq ft.

Panel B: 24 in. × 12 in. × 0.743 in., with $^1/_{16}$-in. 3-ply birch face, and $^3/_{64}$-in. 3-ply birch back; basswood core. Weight, 0.82 lb per sq ft.

DESCRIPTION OF TESTS

The following tests were made:

1 Test in bending as simply supported beam over a span of 18$^1/_2$ in. with a concentrated load across the center of the panel.

2 Test in bending as simply supported beam over a span of 18$^1/_2$ in. with a concentrated load in the center of the panel and covering an area of 1 sq in.

3 Test of crushing strength by means of a concentrated

TABLE 1 RESULTS OF BENDING TEST NO. 1

Load, lb	Deflection, in. Panel A	Panel B
50	0.032	0.035
100	0.060	0.062
150	0.085	0.093
200	0.113	0.120
250	0.138	0.151
300	0.167	0.177
350	0.194	0.203
400	0.221	0.230
450	0.251	0.261
500	0.278	0.292
550	0.300	0.333
600	0.330	.....
650	0.388	.....

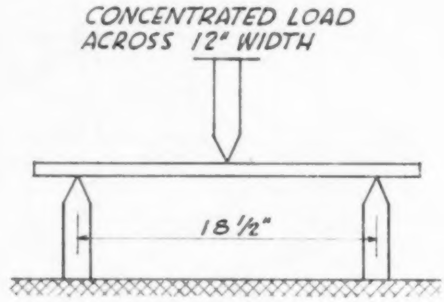


FIG. 2 LOADING CONDITION TEST NO. 1

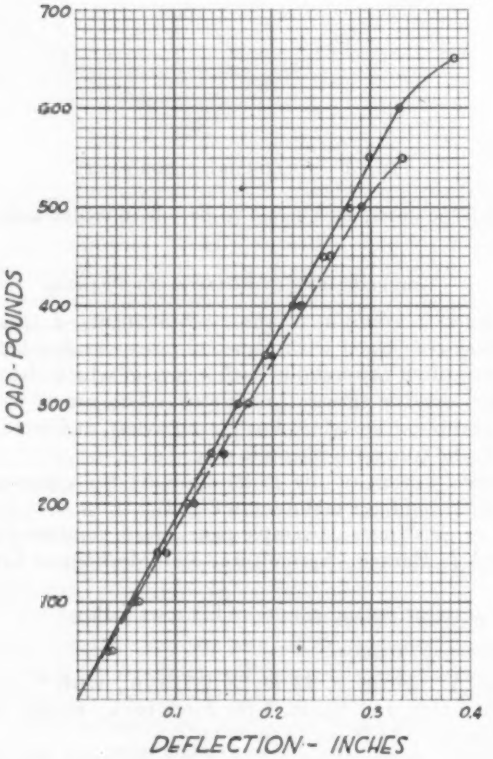


FIG. 3 DEFLECTION CURVES FOR TEST NO. 1
(Full line, panel A; dashed line, panel B.)

load covering an area of 1 sq in. in position between the grids, over one grid, and over cross-grids.

4 Test of shock resistance with beam fixed at both ends over a span of $18^1/_2$ in. by means of a cylindrical bag 6 in. diam filled with 50 lb of shot and dropped from a height of 8 in.

Condition of loading the panel for test No. 1 is shown in Fig. 2, and the results are given in Table 1. Deflection curves for this test are shown in Fig. 3. Fig. 4 shows the loading for test No. 2, and Table 2 shows the results.

The crushing strength of the panel, as developed by test No. 3, is covered by the loading diagram, Fig. 5, and the results are given in Table 3.

In test No. 3 both panels failed in horizontal shear along the glue line between the plywood and the grid core. Panel A is capable of supporting a concentrated load of 600 lb with a deflection of 0.33 in. at the proportional limit. Panel B is capable of supporting a concentrated load of 500 lb with a deflection of 0.292 in. at the proportional limit. Both panels are capable of supporting a concentrated load at their center over an area of 1 sq in. of 300 lb without any evidence of failure. The loads causing puncture in both panels are higher than anticipated and in no case was the rupture carried over into adjacent grids.

The impact tests showed that both panels with fixed ends could safely withstand the shock of a 50-lb bag of shot dropped from a height of 8 in.

The result of these tests was that Type A was specified for the particular restricted contract.

Conditions 4 to 8 did not call for tests.

Both floors tested were approximately $^3/_4$ in. thick and weighed approximately 0.8 psf. In a small panel, the rails add to the per square foot weight more than in a large panel.

The design of the floor permitted the addition of solid spruce

TABLE 2 RESULTS OF BENDING TEST NO. 2

Load, lb	Deflection, in. Panel A	Panel B
100	0.085	0.087
200	0.150	0.157
300[a]	0.225	0.230

[a] No evidence of crushing on the plywood face.

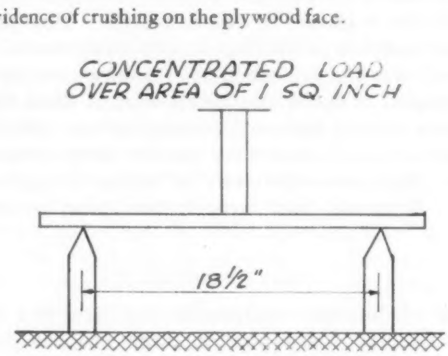


FIG. 4 LOADING FOR TEST NO. 2

TABLE 3 RESULTS OF CRUSHING STRENGTH TEST NO. 3

Location of load	Load at failure, lb Panel A	Panel B
Fig. 5(*a*)	400	370
Fig. 5(*b*)	475	410
Fig. 5(*c*)	650	480

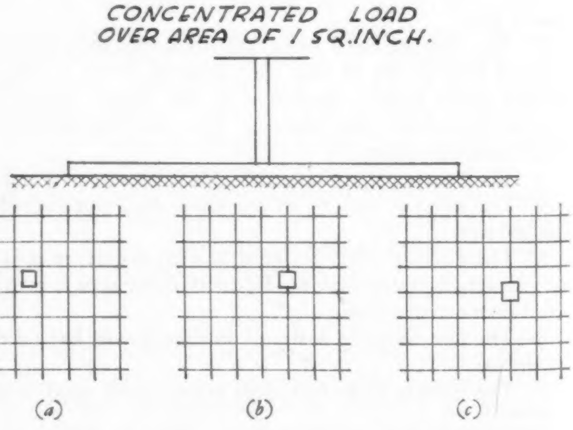


FIG. 5 LOADING DIAGRAM FOR TEST NO. 3

blocks in every area where fasteners and attachments are to be used to meet condition 6.

The addition of a sheet of vulcanized fiber 0.010 in. thick on the underside of the floor took care of condition 7. The dielectric strength of this fiber is 300 volts per unit minimum.

Condition 8 was eventually met by arrangement with a rubber-goods manufacturing plant for the use of its belt press which was 4 ft wide × 25 ft long. This press is a hot-plate press and functions the same as any similar unit in a plywood factory. We arranged to install a woodworking adjunct in the rubber plant. The face panels were made in a plywood plant, but the actual work of manufacture and assembly of other details of the floor was done in this rubber-manufacturing plant.

APPLICATION TO AIRPLANE RAMPS AND FLOORS

Ramps used for loading were designed $^{9}/_{16}$ in. in thickness. The ramp, which is thinner than the floor panel, carried a test load of 500 lb per sq ft with a deflection of $^{15}/_{64}$ in.

Loading rails were attached to the ramps and floors, to be used when the plane carried war vehicles, such as jeeps.

For a floor of this type, skid strips, the same as used in trucks, should be added to take the shock of loading. The $^{1}/_{8}$-in. birch-plywood surface is not punctureproof against sharp boxes and tools being dropped on it. However, it is easily repaired by filling the punctured space with a wood putty or sealer which hardens. There are many types obtainable which when hard have fairly good screw- or bolt-holding qualities. These repairs can be made on the plane without disturbing the floor. The repair of a typical puncture is shown in Fig. 6.

The wearing surface can be improved by the addition of vulcanized fiber or phenolic-impregnated paper which can be glued to the birch panel at the time the panel is being made.

A continuous study of further design and construction of this floor resulted in improvements during the progress of the contract. The floor originally was designed for a concentrated load of 500 lb with a deflection of not more than $^{1}/_{4}$ in. over an $18^{1}/_{2}$-in. span. In the final test before acceptance, it carried a load of 800 lb per sq ft over an 18-in. span with a deflection of $^{3}/_{16}$ in. When the load was removed, the floor assumed its original plane. Eventually the thickness of the floor was reduced from $^{3}/_{4}$ to $^{11}/_{16}$ in. and a 4-ply panel (three plies of basswood, one of fiber) was substituted for a 3-ply birch panel for the back.

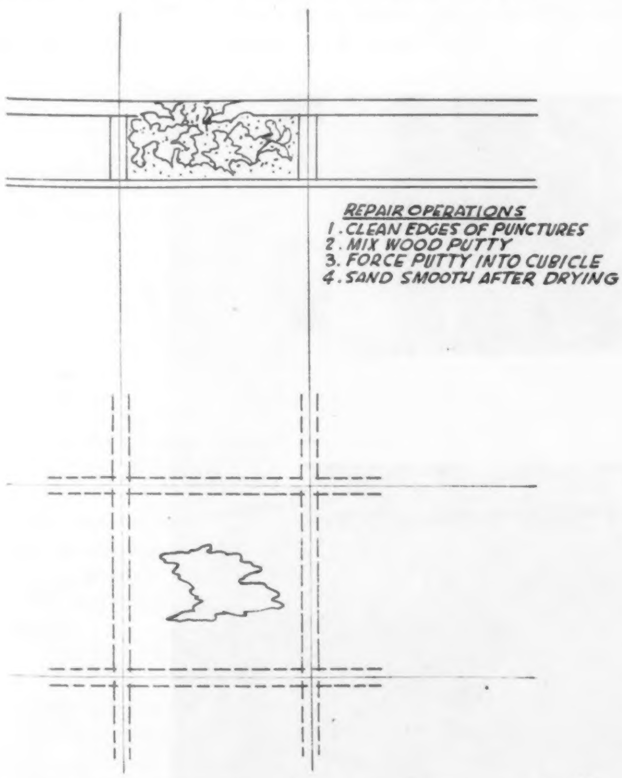


FIG. 6 PROCEDURE FOR MAKING PUNCTURE REPAIR IN FLOOR

FIG. 7 TEST LOAD OF 4240 LB BETWEEN 18-IN. SPANS

The weight of the floor was increased slightly as a result of the introduction of more solid blocking for fasteners and tie-downs than was originally contemplated.

Fig. 7 shows the test in which the total load was 4240 lb between 18-in. spans, or an average of 800 lb per sq ft. The very slight deflection of $^{3}/_{16}$ in. can be noted in the floor panel being tested. Fig. 8 indicates the lightweight of the floor panel. The particular panel illustrated is 4 ft wide, 25 ft long, and weighs approximately 100 lb, or about 1 lb per sq ft. There are two panels to a floor. Fig. 9 shows the floor and ramp installed and in use.

A number of airplane manufacturers have tested the "Hollo-Tech" floor, as it is known, in their own laboratories. A summary of test data is given in Table 4.

To indicate the advantages of the hollow-core panel over the solid panel, a comparison of weights between the hollow-core and solid panel is given in Table 5.

The hollow-core aircraft panel used in the comparison was made up of $1^{1}/_{2}$-in. × $1^{1}/_{2}$-in. mesh, 1-in. stiles and rails with 3-ply $^{3}/_{32}$-in. basswood faces. All comparisons in Table 5 are based on a panel 16 in. × 24 in. and of the thickness shown in the first column of the table.

Theoretically, by reference to Table 6, the weight may be estimated for almost any combination of hollow-core panel made with the construction outlined. In preparing this table, the weights have been based on 1 in. thickness of each material involved.

For example, the weight of a typical hollow-core panel $^{3}/_{4}$

TABLE 4 TEST DATA ON HOLLOW-CORE PLYWOOD PANELS

Description of panel						Static bending			Puncture load, load over sq in.		
Face	Back	Size, in.	Weight, lb per sq ft	Span, in.	End conditions	Type of load	Load at propor-tional limit, lb	Deflec-tion at propor-tional limit, in.	Be-tween grids, lb	Over one grid, lb	At cross grids, lb
3-Ply $^1/_{16}$-in. birch	3-Ply $^3/_{64}$-in. birch	24 × 12 × 0.778	0.83	18.5	Simple	Concentrated across 12 in. width	600	0.33	400	475	650
3-Ply $^1/_{16}$-in. birch	3-Ply $^3/_{64}$-in. birch	24 × 12 × 0.743	0.82	18.5	Simple	Concentrated across 12 in. width	500	0.292	370	410	480
3-Ply $^1/_{32}$ birch $^1/_{28}$ birch $^1/_{32}$ birch	3-Ply $^1/_{62}$ birch $^1/_{62}$ birch 0.10 fiber	56 × 18 × $^{21}/_{32}$	0.88	18	Fixed	Uniform	645	0.33	520	680	760
3-Ply $^1/_{32}$ birch $^1/_{28}$ birch $^1/_{32}$ birch	3-Ply $^1/_{62}$ birch $^1/_{62}$ birch 0.10 fiber	56 × 18 × $^{21}/_{32}$	0.88	18	Fixed one end—Simple other end	Uniform	575	0.27 Taken at center	... Concentrated load, 0.65 sq in.	...	...
3-Ply $^1/_{16}$-in. basswood	3-Ply $^1/_{16}$-in. basswood	24 × 18 × $^3/_4$	0.73	14.7	Simple	Uniform	820	0.175	...	...	...
3-Ply 0.076-in. basswood	3-Ply 0.076-in. basswood	24 × 16 × 1	1.08	23	Simple	Concentrated	800	0.31	285	...	543

TABLE 5 COMPARISON OF WEIGHTS OF HOLLOW-CORE AND SOLID PLYWOOD PANELS

Panel thickness, in.	—Weights in pounds per thousand sq ft— Hollow core	Basswood plywood
$^1/_2$	674	1170
$^9/_{16}$	718	1320
$^5/_8$	763	1470
$^{11}/_{16}$	807	1610
$^3/_4$	852	1760
$^{13}/_{16}$	896	1910
$^7/_8$	941	2050
$^{15}/_{16}$	985	2200
1	1030	2350

NOTE: The larger the panel, the greater the saving in weight psf over regular plywood construction due to the distribution of the weight of the stiles and rails over the larger area.

TABLE 6 WEIGHTS OF HOLLOW-CORE PANELS

Material	Weight, lb per sq ft
Basswood grid ($1^1/_2$ in. × $1^1/_2$ in. mesh)	0.32
Spruce grid ($1^1/_2$ in. × $1^1/_2$ in. mesh)	0.308
Basswood stiles or rails	2.20
Spruce stiles or rails	2.12
Birch plywood	4.00
Basswood plywood	2.50

NOTE: For calculations, the grid dimensions equal finished size of panel less width of framing.

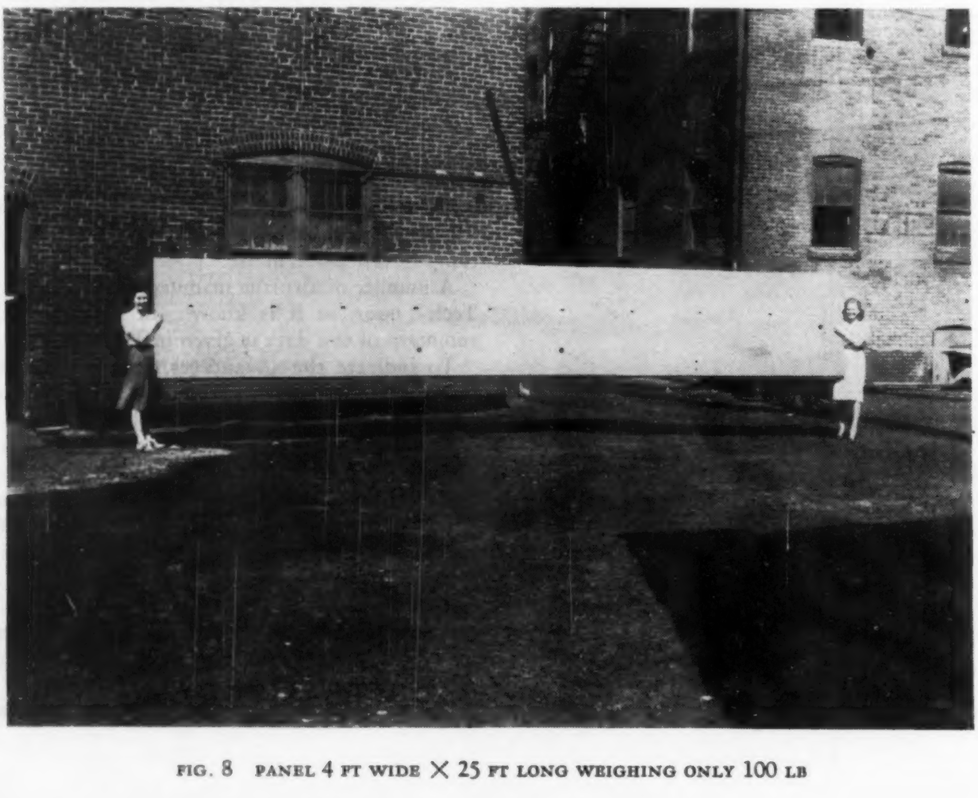
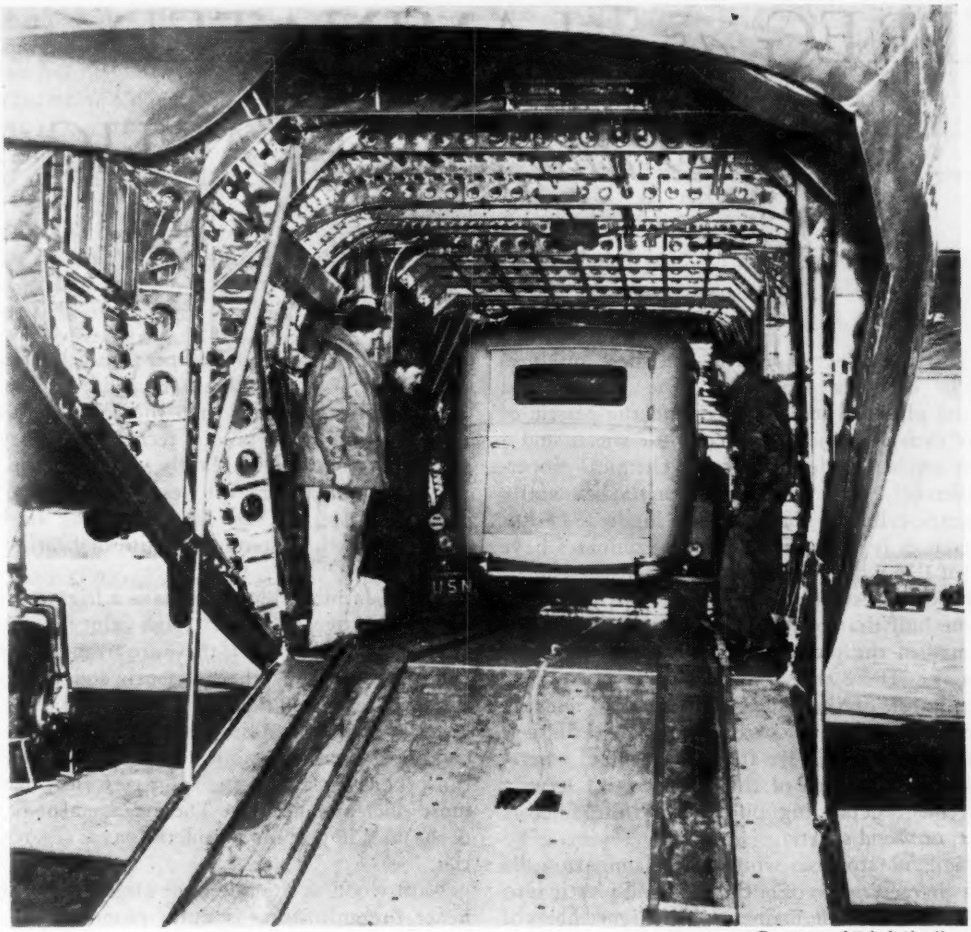


FIG. 8 PANEL 4 FT WIDE × 25 FT LONG WEIGHING ONLY 100 LB



Courtesy of "Aviation"

FIG. 9 FLOOR AND RAMP INSTALLED ANDIN USE

in. × 48 in. × 96 in., birch faces, basswood stiles, rails, and grid one may be computed as shown in Table 7:

TABLE 7

Reducing the above weights to a net thickness basis gives:

Face panel ($^1/_{16}$ in.) 0.0625 × 4.00	=	0.250 lb per sq ft
Back panel ($^3/_{64}$ in.) 0.0468 × 4.00	=	0.187 lb per sq ft
Stiles ($^{41}/_{64}$ in.) 0.0641 × 2.20	=	1.410 lb per sq ft
Grid ($^{41}/_{64}$ in.) 0.0641 × 0.32	=	0.205 lb per sq ft
For a 32-sq ft panel (48 in. × 96 in.) the figures are:		
Birch face ($^1/_{16}$ in.) at 0.25 per sq ft	=	8.00 lb
Birch back ($^3/_{64}$ in.) at 0.187 per sq ft	=	5.984 lb
Basswood stiles and rails, 1.26 sq ft ($^5/_8$ in. × 24 ft) at 1.41	=	1.776 lb
Basswood grid, 30.76 sq ft ($46^3/_4$ in. × $94^3/_4$ in.) at 0.25	=	6.30 lb
Total weight for 32 sq ft	=	22.06 lb
per sq ft (÷ 32)	=	0.690 lb

This type of floor permits a combination of a hollow and solid floor in the same panel. The great advantage claimed is that the floor can be designed to give maximum strength where needed and minimum weight where maximum strength is not required.

FLOORING ADAPTABLE TO OTHER TRANSPORTATION FIELDS

While primarily this floor was designed for the aircraft field, it can be adapted to many other forms of transportation equipment. Perhaps its readiest application would be in the bus field. At one time busses were designed without any regard to holding weight to a minimum and strength to a maximum. Today conditions are different because there is such a divergence in state laws as to the weight permitted on highways that it is necessary now to design a bus so that it will conform to all of the laws of the various states through which the bus operates.

By taking advantage of lightweight substitutes that can be used in place of conventional materials, it has been demonstrated that the total weight of a large intercity bus could be cut approximately 500 lb. This saving has been effected by using the conventional solid-floor design. The present-day bus can be designed to save not only the 500 lb mentioned, but in addition, by the use of a hollow-core floor, at least 250 to 300 lb more can be saved. This of course is a great advantage not alone to the bus manufacturer who is able to turn out a lightweight but strong design, but it also represents economy for the owner who will find a substantial saving in yearly maintenance and operating cost because of this 750-lb saving in weight.

This type of floor can be used to advantage in railway-coach and streetcar design. The flooring can be protected by steel faces where necessary which will make the panel practically fireproof, which of course is desired and demanded today in the construction of a railway coach.

It can be used not so much for flooring as for partitions in the marine field. Here also it can be protected and made highly fire-resistant by combinations of metal or asbestos in the construction of the panel.

Other fields where this type of panel can be used to advantage are for floors and linings of trucks, trailers, and commercial bodies, elevator cabs, department-store backgrounds, and portable-elevator platforms.

COMPREG *as a* LAMINATED WOOD *and as a* PLASTIC

By JOHN F. DREYER

FORMICA INSULATION COMPANY CINCINNATI OHIO

PLYWOOD and thermoset laminates are sheet products with widely different properties. The cross-banded veneer of the plywood manufacturer and the plastic of the laminator are each compounded of cellulose sheets and a binder. Yet their mechanical, electrical, and chemical properties are widely different. They have in common fundamentally the same components, cellulose fiber and resin binder. One of the effective differences is in density. Plastic laminates have a specific gravity of 1.35 which is almost the full density of the materials. Plywood has essentially the density of the wood used, less than one half that of laminated plastics. Some of the differences between the products result mainly from this difference in density. There are several other effective differences. The distribution of the added resin is more uniform in the plastic laminate. One is coated, the other is impregnated. The fibers in the wood plys are well oriented, whereas the fibers in the laminations of the plastic sheet have a diversified arrangement depending on whether the filler is paper, cloth, mat, or wood sheet.

When the plastic laminator uses wood as his lamination, he combines the best characteristics of both wood and plastic into one material. The combination maintains the aligned fibers of the wood and adds the good properties coming from the higher density and added resin of the plastic-laminating process. To the plywood manufacturer the product is simply a laminated wood where the plys are impregnated and compressed. To the plastic laminator this product is a reinforced plastic where the sheets are wood in place of the usual paper or cloth.

COMPREG COMPOSITION

The term "compreg" is generally used to designate the product. This name was first suggested by Fred E. Weick, chief engineer of the Engineering Research Corporation, the first large user of the product in this country, and is now generally recognized. It is made commerically by impregnating rotary-cut maple veneer with a phenolic resin in solution. By drying off the solvent and compressing under heat and pressure the ultimate density is reached and the resin polymerized to its infusable state.

The open hygroscopic cells of wood allow water to penetrate readily and are a cause of its high water absorption. In the manufacture of compreg, the synthetic-resin binder penetrates these cells and impregnates the wood thoroughly. It coats the walls of the cells so that they will be cemented together thoroughly when the wood is collapsed. The new product is rot- and insect-resistant for the added resin protects the wood.

The resin also lubricates the wood so that when it is compressed it is not crushed. If the wood is not properly lubricated, the shear strength parallel to the lamination will be low. The value may be in the neighborhood of 2500 psi, whereas a good product will have a value of over 5500 psi.

The natural binding agents in the wood are actually in greater proportion than the added synthetic resin. Wood is said to be composed of about 60 per cent cellulose and 20 to 25 per cent lignin.[1] The synthetic resin added is less than 20 per cent. The constituents other than the cellulose must be given due consideration in the process technique. They are particularly sensitive to overcure. Mainly for this reason, sheets over 2 in thick are not made by the heated-platen-type pressing process A heavier section can be made using high-frequency electrical heat which produces uniform heating throughout the panel.

The resin binder does not have a high tensile strength. Its value is not over 9000 psi. High value for tensile strength must come from the fibers. If these are arranged in random direction they do not add together efficiently and, although the resulting product is more uniform, the tensile value is low. With unoriented fibers an applied stress will subject the binder to shear, compression, and tension. With the fibers parallel where they can take the tension, the resin performs, mainly in shear, its most efficient function. The arrangement of the fibers is one of the most important considerations as regards physical properties.

With wood as the filler, the alignment of the fibers is good, hence the anisotropy is quite pronounced. This directional character pertains not only to strength properties as tension, compression, and shear but also to moisture expansion, heat transmission, thermal expansion, etc. These are graphically illustrated in Figs. 1, 2, and 3, in which the values given show the directional character of compreg.

The differences in directional properties for parallel-laminated compreg are given for compression, water absorption, and shear. Unless otherwise specified all tests are as of AAF Specification 15065A. All tests of compreg are on material "Pregwood" of density 1.35, supplied by the author's company, and having the physical properties of the foregoing specification.

Compreg, parallel-laminated, has more difference in properties measured in the length and width directions than the usual plastic laminate of cloth. However, it is more homogeneous in its thickness. With impregnated compressed wood, the resin distribution is uniform throughout the thickness of the sheet. Each lamination is homogeneous in its thickness. It could be halved and the same character would remain. This is not true of canvas laminates. Progressing through the thickness of a sheet of laminated canvas, we meet a variety of conditions.

This homogeneity of compreg produces refinishing character The surface can be machined off and the new surface has the same quality as the original surface. This is a quality which solid wood has but is new to laminates. When used as a flooring this quality makes it possible to sand all joining surfaces flush. The new surface can be buffed to a highly lustrous decorative finish. The resin adds decorative quality to the wood.

Again comparing compreg to other plastic laminates, the impregnated compressed-wood product has in its grain direction a

Contributed by the Wood Industries Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

[1] "The Properties and Uses of Wood," by Arthur Koehler, McGraw-Hill Book Company, Inc., New York, N. Y., 1924, p. 152.

higher tensile strength, modulus of elasticity, izod impact, and modulus of rupture.

The high stiffness has made it advantageous for use in electrical switch arms requiring a good snap.

These mechanical values have made the all-compreg aircraft propeller feasible. This is one of the few applications which have developed in this war where plastic has replaced aluminum.

Compreg is tested in accordance with Bureau of Ships Specification 39W2 and Army Air Force Specification 15065A. The latter specification values are given in Table 1.

The values shown in Table 2 are for parallel-grained compreg, parallel-laminated high-strength paper plastic, Grade C canvas plastic, and sugar-maple wood. This table shows a few comparative physical values as given by the standard specifications.

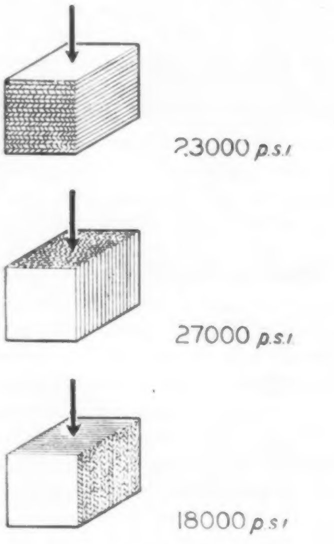


Fig. 1

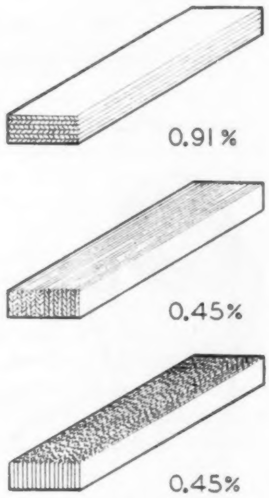


Fig. 3

FIG. 1 COMPRESSION ON 1-IN. CUBE

(Test with machine no load speed of 0.050 ipm; material Pregwood.)

FIG. 3 WATER ABSORPTION 24 HR ON 1-IN. $\times$ 3-IN. $\times$ $^3/_8$-IN. SPECIMEN

(Test with material Pregwood.)

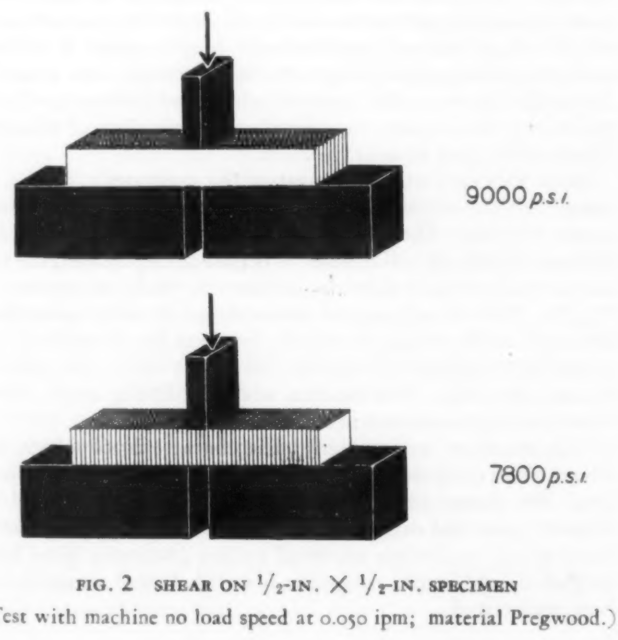


FIG. 2 SHEAR ON $^1/_2$-IN. $\times$ $^1/_2$-IN. SPECIMEN

(Test with machine no load speed at 0.050 ipm; material Pregwood.)

TABLE 1 SPECIFICATION VALUES FOR COMPREG

Specific gravity	1.31–1.37
Izod impact, ft-lb per in. (min)	7.0
Water absorption, per cent (max)	2.5
Swell, per cent (max)	2.5
Shear perpendicular to laminations (square cross section), psi (min)	7000
Shear parallel to laminations (square cross section), psi (min)	5000
Modulus of rupture, psi (min)	35000
Modulus of elasticity, psi (min)	3.0×10^6
Tensile strength, psi (min)	30000
Compression, psi (min)	23000

TABLE 2 CHARACTERISTIC VALUES FOR COMPREG AND OTHER MATERIALS

Material specification	Compreg AAF15065A	Paper plastic AAF12036	Canvas plastic ASTMD-9	Maple-wood ANC-5
Specific gravity	1.31–1.37	1.35	1.35	0.67
Izod ft-lb per in.	7.0	4.0	3.2	...
Modulus of rupture, psi	35000	30000	16000	15000
Modulus of elasticity, psi	3000000	2600000	...	1600000
Tensile strength, psi	30000	28000	7500	...

The izod for maple is in the neighborhood of 10 ft-lb per in. of notch. The modulus of elasticity of the canvas plastic is approximately 800,000 psi. The tensile strength of maple wood is approximately 14,900 psi. Compression values have been omitted since the specifications do not give these values on a comparable basis.

For compreg the coefficients of thermal expansion are different along the grain as compared with those across the grain. Between 20 and 50 C, the coefficient parallel to the grain is 5.9×10^{-6} while perpendicular to the grain, it is 68.7×10^{-6} per deg C. This anisotropy produces internal strains in a cross-laminated product. Cross-laminated compreg is not mechanically as efficient a structure as the parallel-grain product. It is useful, however, for applications where high tensile is not a factor, such as for a metal-drawing die where uniformity and hardness are most important.

In the manufacture of compreg the resin treatment binds the fibers together and improves the weakest property of the wood. The resin does not add appreciably to the true tensile strength. The product is stronger per square inch because more fibers are in a square inch. On a pound basis, the tensile strength in the grain direction of the impregnated compressed wood differs little from the raw wood. However, the tensile strength per pound across the grain direction has been markedly improved. The processing has also improved the shear parallel to the grain.

Another real improvement over raw wood is the moisture resistance. The capillary holes of the wood are collapsed and resin-sealed. Furthermore, the phenolic resin, heat, and moisture combination ties up the hydrophilic groups present in the wood. The natural wood resins are somewhat altered by the

TABLE 3 SPECIFIC VALUES FOR UNTREATED MAPLE AND TWO TYPES OF COMPREG

	Untreated maple	Compreg ⊥ laminations	Compreg ‖ laminations
Shear parallel to grain, psi	2200	9000	7800
Specific gravity	0.62	1.33	1.33
Specific shear	3520	6770	5870
Modulus of rupture grain parallel to load, psi	2000	...	7700
Specific gravity	062	...	1.33
Specific modulus	3200	...	5780
Water absorption, per cent	45	...	1.4
Swell in water, per cent	5	...	1.2

heat and pressure treatment. They reform to assist the binding and moisture resistance.

The specific values in Table 3 include shear values using square jig of AAF Specification 15065A. This table shows a comparison of processed and unprocessed wood. Water absorptions were tested in accordance with Specification 15065A. These particular tests were chosen to show the improvements obtained by the processing.

CHOICE OF WOOD

The choice of wood used will to some degree affect the final properties. In the manufacture of propellers of compreg it is desirable to have a high shear value. It has been found that woods with a straight grain such as birch do not give as high a shear test as the less uniform maple. Under similar conditions of manufacture maple will give a compreg with a perpendicular shear of 8000 psi, while the corresponding value for birch is 6000 psi. The tensile strengths are in the reverse order, birch being about 5000 psi higher than maple. One test on hemlock gave a modulus of elasticity of 5.5×10^6, as compared to 3.6 average for maple. Redwood gives unusually good water resistance. However, impregnating and compressing the various species of wood brings their properties more nearly alike. They can all be made to have the same specific gravity. If the same proportion of resin is kept their physical properties will be more alike in the compreg form than in the natural wood.

The variations which occur in natural wood are averaged and generally minimized by the laminating process. A $^1/_8$-in. lamination is the thickest wood lamination being used. For a finished thickness it takes fifteen of these $^1/_8$-in. laminations to make 1 in. The laminations are compressed to not quite one half their original thickness. Thinner veneers such as $^1/_{16}$ and $^1/_{28}$ in. are used for thin sheets, so that in all cases a number of laminations are used. Furthermore, any variation in the wood becomes well distributed by taking care to shuffle the laminations well before laminating. These factors raise the minimum value which has to be considered by the designer.

Variations will occur from tree to tree of the same species. For example, one test on special selected birdseye maple, unprocessed wood, gave a modulus of rupture of 32,500 with shear of 9300 psi, while a selected straight-grained wood gave a modulus of rupture of 40,700 with the shear at 6800. Variations also occur within one tree. The flexural strength of natural maple wood taken from different sections of one tree are given in Table 4. These values were taken from a section

TABLE 4 FLEXURAL STRENGTH OF NATURAL MAPLE

Heartwood, psi	8300
Outer heartwood, psi	9740
Next to heartwood, psi	11900
Inside sapwood, psi	12050
Sapwood next to bark, psi	12100

of one log to show the variations in strength which may occur in different sections.

To obtain the best properties, it is necessary to select the wood very carefully.

PHYSICAL CHARACTERISTICS

Mention should be made of certain physical characteristics. For compreg the load-deformation curve is quite straight with no well-defined yield point at the end. This lack of yield is characteristic of plastics and is conducive to notch sensitivity. A notched tensile specimen will give 60 per cent of the value of a smooth specimen. This factor must be taken into account in design. Radii should be as large as practical for all angles.

Izod values are high for a cellulose-filled plastic. Since the

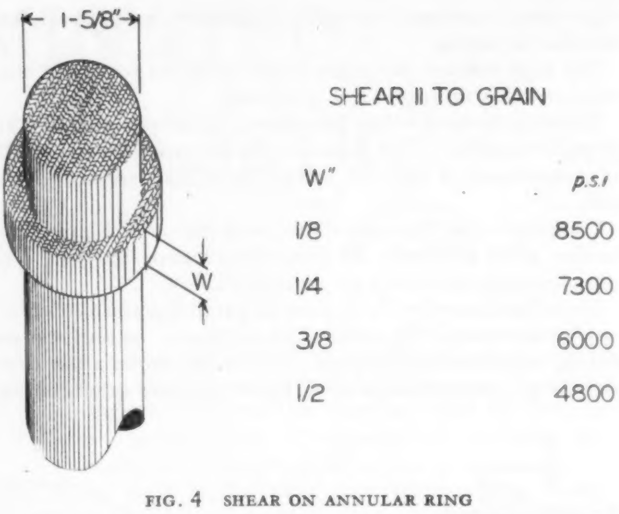


FIG. 4 SHEAR ON ANNULAR RING

(Test with machine no load at 0.050 ipm; material Pregwood.)

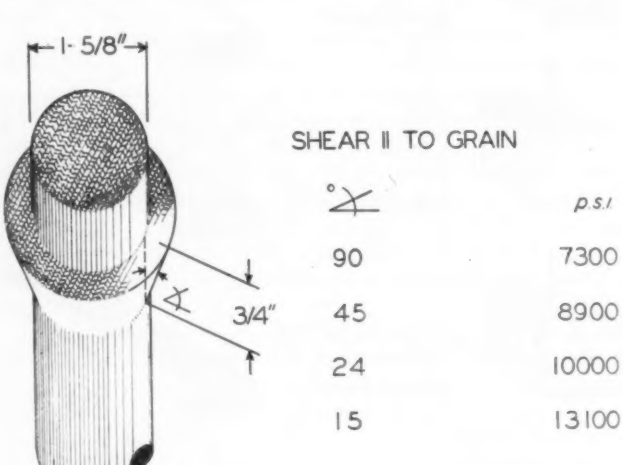


FIG. 5 SHEAR ON ANNULAR RING

(Test with machine no load at 0.050 ipm; material Pregwood.)

product has almost reached its ultimate density, its compression-bearing value is excellent. It cannot be readily dented or crushed. Shear, parallel to the grain and perpendicular to the laminations, is greatly influenced by the degree of grain crossing which occurs between laminations. Maple veneer if laid up with the sheets parallel lengthwise will normally have up to 15 deg angle between the grain of alternated laminations. In processing care is taken to alternate the grain slope of adjacent sheets when good shear is required.

Shear will vary with the length of the shear area. In Fig. 4, values are shown for shear on an annular ring with different tooth lengths. These values show the shear strengths for different widths of collar when it is pushed off. Changing the angle of the bearing face also affects the result, as appears in Fig. 5. This second series of values shows the effect of varying the angle of the surface to which the shear face is applied. If compression is present perpendicular to the shear, the value is increased greatly. For the test with the 15-deg angle, there was considerable tension in the testing ring.

This relatively new material has characteristics which are like those of other materials and yet has its own unique properties. For design and application, these properties should be known; good use can be made of them. By applying laminated-plastic technique to wood certain properties have been magnified, and at the same time a well-balanced material has been maintained.

METLBOND—*A Metal Adhesive for* AIRCRAFT

By G. G. HAVENS

CONSOLIDATED VULTEE AIRCRAFT CORPORATION, SAN DIEGO, CALIF.

A RECENT and important trend in aircraft is the use of organic adhesives for bonding together metal and various other materials. It is being recognized by more and more engineers that smooth leading edges, trailing edges, and other skin surfaces, so important to high-speed planes, require a continuous bond of the skin to the underlying surfaces. This is not the only advantage to be obtained from a continuous bond; the stiffness and strengths of assemblies having a continuous bond have been shown to exceed those having intermittent types of fastening such as riveting or spot welding. The continuous-bonding method permits the use of unskilled labor in place of skilled labor now needed for riveting. The cost of assembling certain parts can be reduced to a fraction of the present riveting costs. However, this does not mean that bonding will be a cure-all or completely eliminate riveting or spot welding. Bonding has certain disadvantages, some of which are inherent, so that the judicious use of the continuous-bonding method is required at all times. Possibly more important still is the use of new materials that are made available by the bonding method. A noncorrosive attachment method is important in the use of magnesium alloys. Fiberglas, with its very high tensile strength, can be bonded to metals where riveting or spot welding would be impossible.

The need for the development of good adhesives for replacing rivets and other methods of attachment in aircraft has been recognized for years; however, it is only recently that this type of development has been given the attention it deserves. The lack of such a development can be attributed in a measure to the fact that the aircraft industry, which had the incentive, did not have the "know how" and, vice versa, the rubber and chemical industries which had the "know how" did not have the incentive. This was particularly true before the war when the sale of aircraft was so limited that the volume of adhesive used would not be sufficient recompense for the needed development work on adhesives. Even at the present time the dollar volume of cement which would be used by all the aircraft industries, assuming that the rivets were replaced 100 per cent, would be relatively small compared to many rubber and chemical items.

It is not surprising, in view of this, that the pioneering work on adhesives for replacing rivets was done by a concern which, due to the war, became interested in the manufacture of both adhesives and aircraft. Although the pioneering work by this concern produced an adhesive having satisfactory physical properties, the difficulties involved in using it in large-scale production were sufficient to limit its usefulness.

DEVELOPMENT OF METAL ADHESIVES

Bonding to metal is not new. The adhesion of rubber to steel by means of brass-plating has been used for years by the rubber industry for such items as shock absorbers, mountings, and automobile accessories. Besides brass-plating for bonding to metals, cements, such as rubber hydrochlorides, have been used for bonding to steel and other metals, including aluminum alloys. Such cements were forerunners of the more recent metal adhesives.

A first requirement of a satisfactory adhesive is adequate shear strength; however, this is not the only requirement or the most difficult one to meet. A good adhesive must have satisfactory flexibility, as well as resistance to heat and cold, resistance to aromatics and salt water, resistance to aging, and resistance to fatigue. Even after these physical requirements are satisfied it may not be concluded that an adhesive will compete with riveting or spot welding. Before wide-scale use can be expected, it is necessary that the attachment with cements be not only superior in quality but also less expensive.

The rubber-hydrochloride adhesives were unsatisfactory at temperatures of —70 F, and the shear strengths were not as high as desired. The aromatic and salt-water resistance was low and constant bond strength to Alclad was difficult to obtain. More recently there have been two adhesives developed by different concerns, which do not have the foregoing difficulties, and which would have been practical for large-scale use except for the necessity of high curing pressures, necessitating the use of heavy and expensive jigs for assembling aircraft parts.

Realizing the deficiencies of previous cements, the author's company undertook the development of a bonding process which would have satisfactory physical properties, and sufficiently low curing pressures so that expensive jigs could be avoided. It was believed that such a development would result in a production method of attachment which would supplement or replace riveting and spot welding for many applications. Examination of several adhesives requiring high curing pressures indicated that adhesion to the metal was not the difficulty and that the high pressure required was necessary to obtain adequate flow of the cement to provide sufficient contact. At first, attempts were made to produce a single cement which would flow at low curing pressures and still retain the desired physical properties. Later, it was decided to make a different approach to the problem. As a result, a method was developed employing two adhesives—one having a synthetic-rubber base which gave flexibility and adhesion to the metal; and the other having a plastic base which had a sufficiently low viscosity during cure to provide the required flow at low curing pressures. It was found that the combination had the required physical properties and, in addition, could be applied in production without the necessity of expensive jigs.

THEORY OF ADHESION

The theory of adhesion is still in an elementary state. From elementary physics we learned that there are two types of forces which hold materials together, cohesive forces and adhesive forces. Cohesion is the attraction between like materials, and adhesion is the attraction between unlike materials. From the definition, one can consider cohesion a special case of adhesion. The importance of adhesion cannot be overemphasized. The strength of metals such as aluminum and steel is largely due to adhesive forces. The precipitation of carbon between crystals in carbon steels and copper in aluminum alloys results in high intercrystalline adhesion and accounts for the high strength of these alloys. We can expect the develop-

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ment of new light alloys based upon obtaining better intercrystalline adhesion. The low strength of many of the present laminated plastics can be traced to the poor adhesion between the plastic and material which it impregnates.

In the Metlbond development, we are interested in the application of organic adhesives for producing high-strength assemblies. The theory of this type of adhesion is even less satisfactory than the theory for internal metal adhesion. As far as is known now there are three types of forces by which one can achieve adhesion of an organic material to metal. One is a primary chemical bond between the metal or its oxide surface and the organic chemical. This is the strongest type of bond and the most resistant to high temperatures. Another, the interstitial type of bond, is also of a chemical nature and is usually explained as due to secondary valences. Oxygen, for example, has an ordinary valence of 2 but also has two secondary valences. The adhesion of the nylons to glass and other materials is explained on this basis. This type of adhesion may be strong at room temperatures but usually is not as resistant to high temperatures as primary bonds. The third type, mechanical interlocking, is ordinarily deficient in strength. The strength of this type of bond depends upon the roughness of the surfaces to be bonded. In the case of the chemical bonds, the strength is greater, the smoother the surfaces. The best Metlbonds are obtained with smooth surfaces and are comparatively resistant to high temperatures, which would indicate a primary chemical bond. Although these theories may explain adhesion to a degree, there are many materials which according to the theory should have good adhesive properties, but still do not. As previously stated, a great deal remains to be done before a satisfactory explanation of adhesion is obtained.

METLBOND COMBINES SEVERAL ADHESIVES

In its present use, the name Metlbond is a Consolidated Vultee Aircraft Corporation trade name for a combination of adhesives for bonding metals. Some or all Metlbond components may be purchased from outside concerns. At the present time most of the Metlbond components were developed by Consolidated Vultee Aircraft Corporation; however, a number of adhesives developed by others are under consideration.

It was necessary to develop several forms of Metlbond to meet the large variety of requirements needed in the assembly of various production items. Metlbond materials are prepared in liquid, paste, and tape forms. Spraying, brushing, spreading, and tape methods of application are used. Some recently developed types of Metlbonds are as follows:

1 The original high-pressure, high-temperature, single-phase, synthetic-rubber base requires 100 psi curing pressure at 330 F for 20 min. The adhesive is sprayed onto the parts to be bonded.

2 A low-pressure, high-temperature, two-phase Metlbond requires 15 psi curing pressure at 330 F for 20 min. The synthetic-rubber component is sprayed and a plastic component brushed onto the parts to be bonded.

3 Two types of tape have been developed; one which requires 250 F curing temperature; the other 330 F curing temperature, both requiring a curing pressure of 100 psi. The high-temperature type has the highest shear strength and best heat resistance, but is not satisfactory where the parts contain certain organics unstable at 330 F.

4 A very low-pressure high-temperature Metlbond has been developed requiring a curing pressure of 1 psi or greater, and a curing temperature of 330 F. The shear strength of this type is approximately $^2/_3$ that of the first two types.

Although these Metlbonds were developed principally for metals, they also can be used for most solids. Solids which have been successfully bonded are aluminum alloys, magnesium, steel, zinc, cadmium, fiberglas, cotton and rayon, several plastics, woods, and rubbers.

SPECIAL METLBONDING PROCEDURES

The "Metlbonding" of some materials requires special procedures. The bond between synthetic-rubber, Metlbond, and glass fails when subjected to prolonged sunlight. To avoid this the plastic type of Metlbond is used next to glass. On the other hand, the adhesion of the synthetic-rubber Metlbond to transparent thermosetting materials seems to be unaffected by sunlight.

As previously mentioned, the shear strength of an adhesive is not the only requirement or the most difficult one to meet. There are a number of adhesives that have higher shear strength than the Metlbonds. Shear strengths in excess of 6000 psi, using plastic adhesives between metals, have been reported. The shear strength of Metlbonded joints is approximately 3000 psi, compared to about 1800 psi for the average riveted joints. A shear strength of 3000 psi is believed satisfactory for most practical applications. The Army Air Forces, Wright Field, have conducted an extensive test program on various adhesives and find that plastic joints are too brittle, which results in stress concentrations so that the high shear strengths are realized only on small overlaps and small samples. Also the brittleness results in poor impact and peel resistance. The effect of brittleness is usually accentuated at low temperatures.

A combination of layers of the rubber and the plastic adhesives seems to possess the beneficial properties of each adhesive. The impact and peel resistance of the combination is essentially constant from —70 F to +160 F. It should be remembered, however, that none of the continuous-type bonds is as good as rivets for peel or stripping resistance. For this reason, thin sheets bonded together require a tack rivet at each end of the bond. For most uses, Metlbond can be considered satisfactory for temperatures between —70 F and 250 F, and up to 300 F for certain applications subject to low stresses.

SPECIAL APPLICATIONS

An example of the use of Metlbond for new applications is the aluminum fiberglas sandwich, in which one or more layers of high-strength fiberglas are bonded between two layers of aluminum. This results in a sheet composite of superior stiffness and tensile strength when compared to aluminum alloys on a weight basis. More important still are its sound-deadening properties. Applied as skin to the fuselage of an airplane, the reduction in drumming noise is considerable. This material is being applied to some of the newer planes, and an extension of its use is expectedas soon as production facilities become available.

Another example is the attachment of plastics, such as cast methacrylate resin (Plexiglas) to aluminum. The Metlbond is sufficiently flexible to allow for the difference in thermal expansion of aluminum and Plexiglas. Likewise, experiment and theory have shown that it is possible to bond steel, up to $^1/_4$ in. thick to aluminum, even though the thermal-expansion coefficients of these metals differ appreciably. In this case, the Metlbond also serves as an insulator to prevent corrosion between the different metals. The magnesium development program is closely linked to the Metlbond development because of the corrosive action between magnesium and aluminum.

Plastic dies, jigs, and fixtures are susceptible to breakage in handling in the factory. This tendency can be greatly reduced by Metlbonding steel sheets to the plastic surfaces. Such plastic dies, jigs, and fixtures are being used extensively by the author's company.

A great deal might be said regarding the necessary equipment and jigs required in conjunction with the application of Metlbond. For purposes of this paper, it will suffice to state that no one method is used to the exclusion of others; ovens, heated presses, vacuum bags, pressure bags, and molds will be used depending upon the particular application.

(Continued on page 73?)

AN ELECTRICAL VIBRATOR

Its Application to the Feeding, Mixing, Weighing, Packing, Drying, and Cooling of Materials

By HERBERT J. FLINT

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THE principle of the electrical vibrator described in this paper may be understood by reference to Fig. 1.

1 The main frame is a heavy casting or steel member which acts as a reactionary mass in the vibrator and essentially as its foundation.

2 The vibrator bars are fastened rigidly at both ends of the main frame but are free to flex at their centers.

3 The center clamp is mounted within the main frame, rigidly attached to the vibrator bars at their centers but free to oscillate without touching the main frame. The center clamp directly connects the power unit to the deck or tool to be vibrated.

4 The vibrating motor consists of a stator mounted on the main frame and an oscillating armature fastened to the center of the vibrator bars by means of the center clamp. An air gap separates the armature from the stator at all times so that no physical contact takes place.

The power unit, or vibrator, takes its energy from alternating current or direct pulsating current. Either of these currents, when passed through the stator, creates a series of interrupted magnetic pulls on the armature. One half of each vibrating stroke is powered by one of these magnetic pulls. During this half of the stroke the vibrator bars are bent toward the armature as indicated in Fig. 2 by the line *A-B-A*.

A restoring force is thus built up in the bars, and when the magnetic pull is interrupted, this force supplies the power for the second half of the vibrating stroke.

The bars return to their former position and by their own momentum on to a position *A-C-A*, at which point, in a properly tuned machine, another magnetic pull begins. Thus the bars complete one full vibration, from *A-C-A* to *A-B-A* and back to *A-C-A*, with each electrical impulse.

The length of stroke therefore is adjustable from the maximum downward. The maximum stroke allowable depends upon the type of machine and may be $^1/_{32}$, $^1/_{16}$, or $^1/_4$ in.

It is important to remember that at no time during the stroke do the stator or armature faces come into actual contact. The timing, or tuning, of a vibrator is accomplished by selecting the proper combination of vibrator bars as to thickness and number, which, with the mass to be vibrated, will give the proper natural mechanical frequency to the vibrator.

The natural mechanical frequency increases as the number and thickness of the bars increases, and decreases as the vibrating mass increases. Thus the vibrator responds definitely to either a change in bar setup or to a change in the mass of the deck. Once the machine is properly set up the balance does not change and thereafter operates as a balanced vibrator. The deck or tool must be properly designed to withstand vibration.

All vibrators must be either suspended or supported by means of absorbers, or cushions, to prevent transmission of vibration to supporting structures. When vibrators are properly suspended or supported, the building structure need be only strong enough to carry the dead weight of the equipment. Rheostats, motor generators, rectifiers, or electronic generators are furnished for operation.

Contributed by the Materials Handling Division and presented at the Semi-Annual Meeting, Pittsburgh, Pa., June 19–22, 1944, of The American Society of Mechanical Engineers.

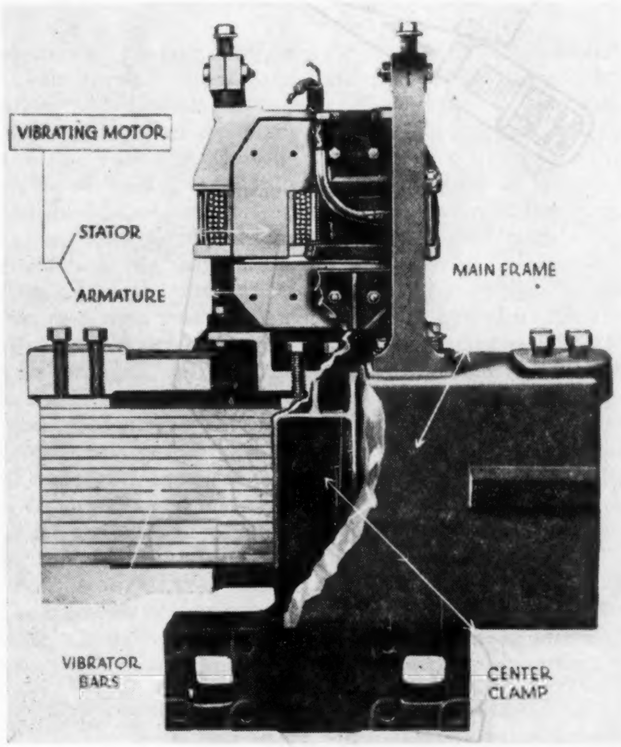

FIG. 1 POWER UNIT OF ELECTRICAL VIBRATOR

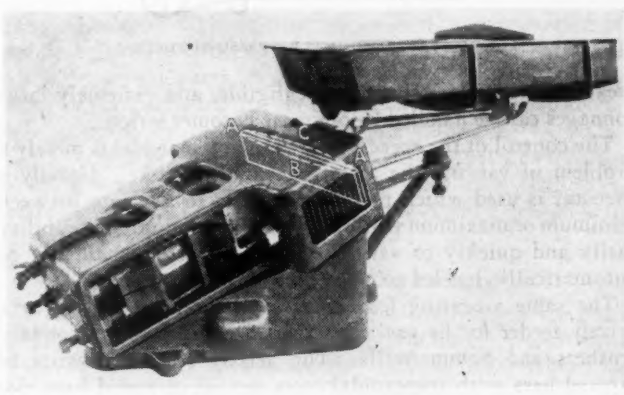

FIG. 2 MOVEMENT OF VIBRATOR BARS

VIBRATING FEEDER

A few of the principal uses of the vibrator are as follows:

The vibrating feeder is illustrated in Fig. 3. The power unit is attached to the feeder deck at a slight angle, usually 20 deg. In operation, as the deck moves forward, it also moves upward at this angle, and as it moves backward it descends at the same angle. Material on the deck is lifted forward and upward. However, the material, which is free to move, does not return

with the backward movement of the deck but falls under the slower force of gravity until it is intercepted by the next forward stroke.

Thus while the motion has the appearance of a uniformly flowing stream, it is in reality a continuous series of short forward hops which are imperceptible to the eye.

This hopping action keeps the material in suspension so that there is no sliding action on the deck surface. Abrasive

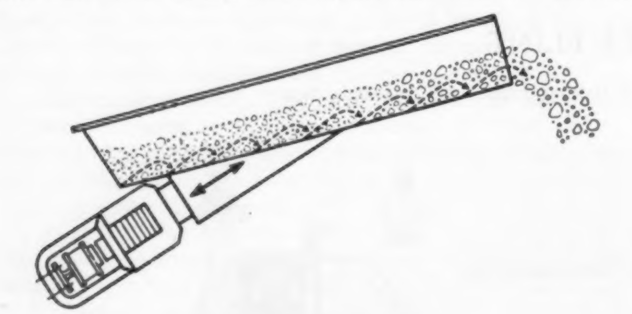

FIG. 3 FEED MOVEMENT

FIG. 4 FEEDING AND BY-PASSING FINES

wear on the deck is therefore negligible, and extremely large tonnages can be handled before wear becomes serious.

The control of the speed of travel of any material is merely a problem of varying the amplitude of the stroke. Usually a rheostat is used which permits changing to any rate between minimum or maximum while the feeder is running. The ability easily and quickly to vary the feed rate, either manually or automatically, has led to many uses of the device.

The same vibrating feeder has been extensively used as a grizzly feeder for by-pass fines around primary and secondary crushers and hammermills. The grizzly section consists of tapered bars with trapezoidal cross section or round bars, depending upon the application. Grizzly bars are constructed of wear-resisting metal such as cast manganese steel. A typical installation of this machine is shown in Fig. 4 where the unit is located at the bottom of an ore pass and discharges run-of-mine feed to the crusher at rates up to 500 tons per hour.

BATCHING MATERIALS FOR WEIGHING

Another well-known use of the vibrator is the accurate batching of one or more materials for weighing. Here the scale, by means of photoelectric cells or mercury relays, controls the feeder so that the bulk of the batch is fed to the weigh hopper at high speed, after which the feeder is automatically slowed down for the dribble, or trim. Hence the batch is automatically weighed with speed and accuracy. Fig. 6 shows the charging vibrating feed, the scale hopper, and a discharging vibrating feeder which automatically discharges the weigh hopper to a belt conveyer.

Vibratory feeders are sometimes water-jacketed for feeding furnaces and spreading materials on belts, screens, and picking tables. A typical application of the vibrator as a conveyer used for severe hard service is shown in Fig. 7.

Fig. 8 shows an 80-ft pan conveyer used for spot-charging a reverberatory furnace. One operator now serves two furnaces where formerly a complete crew was necessary to keep a furnace in operation and to work in gaseous, hot, and dangerous surroundings.

FIG. 5 FEEDING RUN-OF-QUARRY ROCK

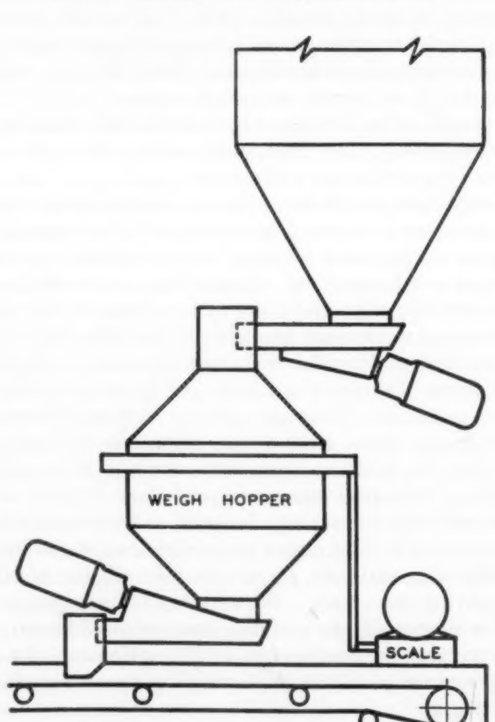

FIG. 6 BATCHING AND DISCHARGING SCALE FEEDERS

CONSTANT-WEIGHT FEEDER

Fig. 9 is a schematic view of a constant-weight feeder. Essentially it consists of three parts:

1 The vibrating feeder, which is automatically and instantly controlled by the weighbelt.

2 The weighbelt is usually made of rubber. It is mounted on a scale and pivoted so that as material is carried toward the discharge end or fulcrum point, the sensitivity of its weight decreases to zero at the point of discharge. The movement of the weighbelt either up or down causes a movement of relays which instantly change the vibrator, or stroke, to restore balance. For example, if the feeder should overfeed, a weight correction would take place to bring the weighbelt back into balance. As this overfeed advances toward the fulcrum point it has a diminishing effect upon the scale, and when it discharges it does not affect the balance of the rest of the material on the belt.

3 The control box is the means provided to receive automatically the signal from the weighbelt, and, in turn, it instantly corrects the feeder to the proper rate.

The weighbelt is usually driven by a synchronous motor and the scale is calibrated in pounds per foot of belt. Hence the total weight is computed merely by counting the number of feet traveled by the belt and multiplying it by the poise setting. To illustrate, if the poise is set at one pound per foot of belt, and the belt is driven at 10 ft per min, then the rate is 10 lb per min, or 600 lb per hr. This method of operation is widely used where the feed rates are well established and are not subjected to frequent changes or where there is no necessity to vary the feed rate by remote control.

Where remote control of the feed rate is desired, the reverse of the foregoing procedure is used; the poise, or scale setting, is fixed and the speed of the belt is varied. In this case, it is

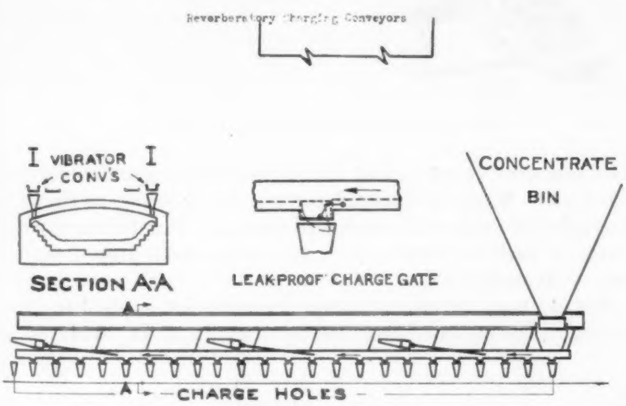

FIG. 7 REVERBERATORY CHARGING CONVEYERS

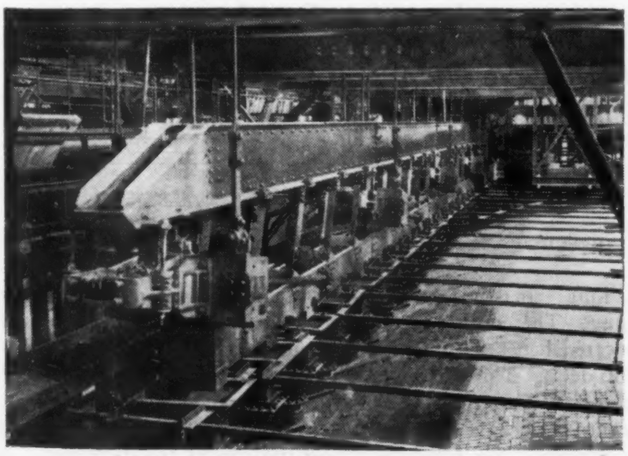

FIG. 8 SPOT-CHARGING REVERBERATORY CONVEYER

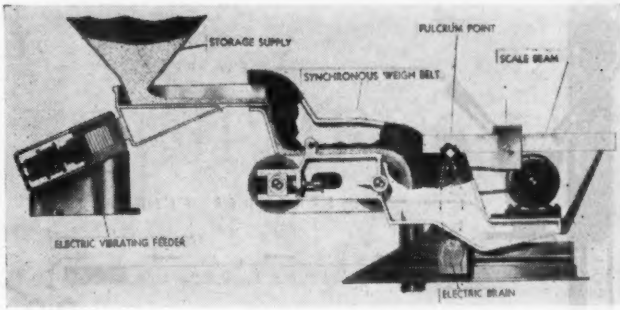

FIG. 9 CONSTANT-WEIGHT FEEDER

necessary to measure accurately the number of inches or feet the belt travels. The actual weight delivered by the machine will be the product of weight put on the belt per unit of length, and the number corresponding to the belt-length travel which the recorder shows. Thus if the poise were set to load the belt at one pound per foot, and in any period of time the recorder indicated a travel of belt of one thousand feet, then the machine would have delivered one thousand pounds. It should be noted that during the time interval to travel one thousand feet the rate, or speed, of the belt may have varied from maximum to minimum many times, and therefore the rate of discharge from the machine, at any instant, is indicated by its belt speed. Usually the variable-speed belt is used where the feeder is to followa demand curve, which may be constantly changing or stationary. The applications of this are too numerous to mention. It would be typical, however, for the feeder to follow a flow meter, the boiler pressure, or the power demand of a motor, or for it to be interlocked with similar machines to blend, or proportion, a number of different materials continuously.

Feeders of this type have been used for delivering as little as two pounds per hour and as high as 500 tons per hour. Accurate, continuous proportioning of any number of materials has simplified many heretofore difficult batching operations.

VIBRATING LOOSE MATERIALS DURING PACKING

The vibrator has been useful in problems of packing loose materials. When used for packing barrels the vibrator is equipped with a heavy, rigid, vibrating head or platen. Vibration is applied vertically, or at right angles, to the bottom of the container. Thus the packer action is a combination of particle agitation within the mass which releases entrained air and causes the particles to move together, and a secondary jolting of the barrel on the packer which takes place at an entirely different frequency. This jolting causes the barrel to bounce on the platen. The combination of these two forces results in maximum density increases. Normally, if the material is such that it can be densified, the maximum density will take place in 30 to 90 sec.

APPLICATIONS TO DRYING AND COOLING

So far this paper has been confined to high-speed vibrators running at 3000 to 7200 vibrations per minute. Other types of vibrators run at slower speeds—1200 to 3000 vibrations per minute. Vibrators of this class have been developed for processing equipment such as drying and cooling. Standard 60-cycle current is used and electronic devices are furnished which produce pulsating direct current with instantaneous and automatic control. To illustrate, assume a drier five feet wide by one hundred feet long to be used for material which must be exposed to the drying surfaces, either direct or indirect, for ten minutes. The required speed of travel in this case will be 10 ft per min. The stroke or amplitude necessary to maintain this speed is known; and incorporated in the electronic device is an adjustable, automatic, amplitude control, which, when set to the desired stroke, will thereafter maintain that

stroke regardless of load, voltage fluctuations, or temperature changes.

Fig. 10 is a typical flow sheet of an indirect-heat-drying and cooling system. The vibrators require little headroom and may be arranged in tiers. Normally these units are five feet wide and are built in 10-ft sections and arranged for coupling together and building into any desired length. Hot air is circulated within a jacket of the drier, hence the material is not exposed to the drying medium. Rolls and screens are provided where needed and the final dried product is cooled before packing.

Where materials are quite granular the drying is often done by direct contact with heated conditioned air. Usually in this type of drier, wire cloth or perforated plate is used for the conveying surface.

Fig. 11 shows a 5 × 10-ft direct-air-type drier complete with spreading feeder, air distributing box, and unit heater.

Fig. 12 shows a typical indirect cooler complete with spreader.

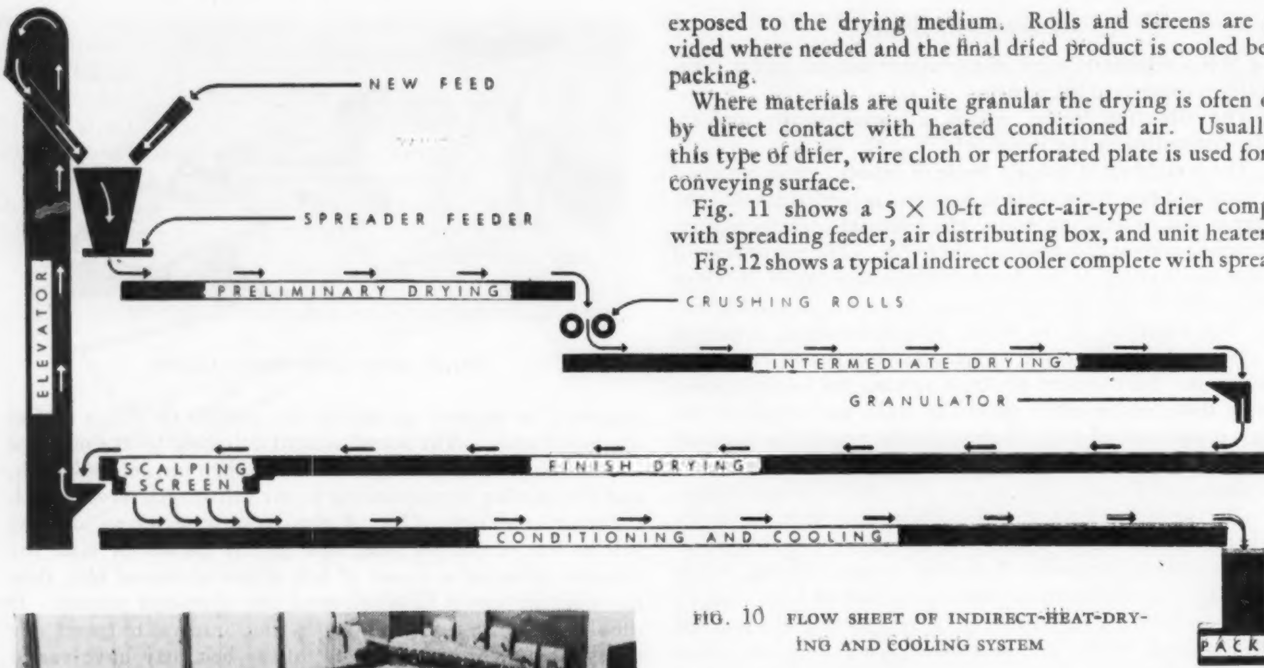

FIG. 10 FLOW SHEET OF INDIRECT-HEAT-DRYING AND COOLING SYSTEM

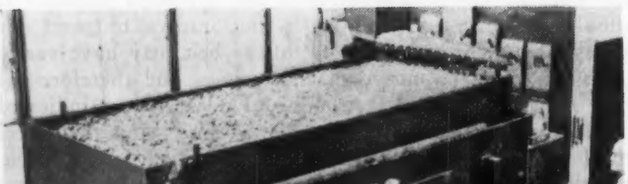

FIG. 11 DIRECT-HEAT DRIER

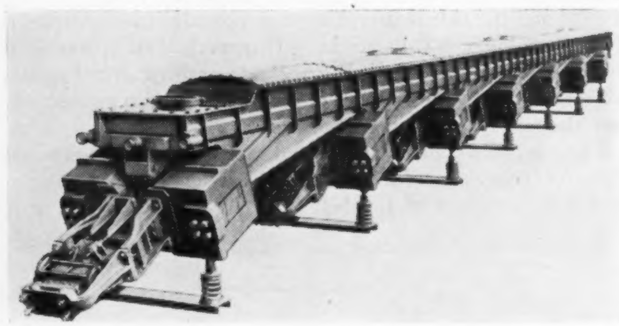

FIG. 13 JACKETED INDIRECT COOLERS

Here the conveying surface is enclosed to protect the material from air. Water is sprayed on top and bottom as thus the material is cooled as it is conveyed forward. The discharged material is gathered into a chute and drops into a drum mounted on a vibrating packer.

Fig. 13 is an excellent example of vibration applied to processing. The enclosed jacketed conveyer is 30 in. wide × 50 ft long. It is but one section of a cooling system about 110 ft long. The cooling medium is carried in high-pressure jackets located beneath the conveying surface and along the sides of the deck. The material will burn when exposed to air, and therefore the atmosphere within the cooler is nitrogen. All joints between sections are gas-tight as the material is highly poisonous. Six windows along the top of the deck make it possible for the operator to inspect the material as it is cooled.

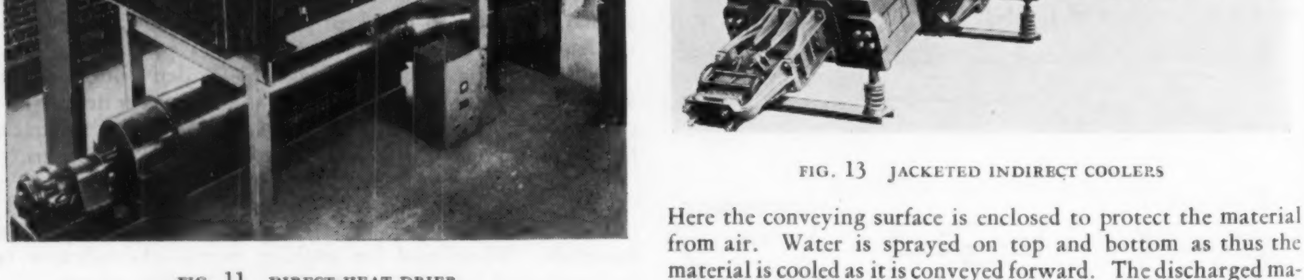

FIG. 12 ENCLOSED INDIRECT COOLER

FATIGUE-TESTING METHODS *and* EQUIPMENT

By H. W. FOSTER and VICTOR SELIGER

RESEARCH ENGINEERS, LOCKHEED AIRCRAFT CORPORATION, BURBANK, CALIF.

TREMENDOUS strides toward improvement in airplane structural design have been and are now being made. Virtually all of our progress in this field of engineering has been achieved through the development of a comparatively broad empirical knowledge of the static strength of aircraft elements. However, it is now becoming increasingly evident that to maintain this progress we must obtain basic data describing the fitness of these elements for service (1).[1] Since the loads imposed on an airframe in service are essentially dynamic, i.e., are continually changing, it is likewise evident that such basic data must, in general, relate to the dynamic strength of the airframe and of its components. Hence since most dynamic loads are applied at relatively low strain rates, the most essential piece of apparatus to be used in connection with the procurement of this information is a properly designed fatigue machine. It is the purpose of this paper to examine briefly the more important considerations to be employed in fatigue testing, to examine the advantages and limitations of some of the more widely used methods, and to discuss thoroughly the subresonance fatigue-testing technique and apparatus developed and presently used by the authors' company. The need for such a paper has become apparent in view of the numerous requests made to Lockheed Structural Research Laboratory for information regarding its fatigue-testing methods and data.

The subject we have selected is complicated, since the fatigue strength of a material or a construction may depend on a great number of variables. These include such factors as maximum and minimum stress in the loading cycle, number of repetitions of stress, surface conditions, and speed of loading; variables that must be investigated by means of a most expensive and time-consuming type of test. Great care must be exercised in planning the tests in order that the variables evaluated may be related to loading conditions actually encountered, and that the results may thus be applied directly to structural design.

GENERAL METHODS OF FATIGUE-TESTING

At the present time numerous types of fatigue-testing equipment are being used. These vary widely in such features as the mechanical principles involved, type of construction, type of specimen used, speed of operation, and the kind of loading applied to the specimen. There are machines which will apply variable flexural stress to a small cylindrical or flat material specimen and others that will impose variable torsional or axial loading. The stress may be imposed by means of determined loads or moments, or by measured deflections or strains. The loading apparatus may resonate at or near the testing speed, thus utilizing the resonance principle as a means of load amplification, or the load may be directly applied.

But no matter what principles are involved, each type of fatigue-testing machine possesses inherent limitations, some of a serious nature, which must be recognized by the research engineer who uses the machine and also by the design engineer who applies the data thus obtained in his calculations. Such limitations as high construction or operation cost are to be weighed, but are seldom as serious as the use of equipment which involves inaccurate means of determining the imposed stresses, or which fails to provide a type of loading that can be correlated directly with the pertinent design conditions.

Arising out of our experience, we suggest the following specifications that may be followed to advantage in the design of a fatigue-testing apparatus for use by the structural research engineer:

1 The apparatus should be adaptable to test the fitness of the material or structural component for the use desired. This cannot be emphasized too strongly, and until the causes of fatigue of materials are more clearly understood, we must design our tests to simulate actual loading conditions. Even in the analysis of so-called fundamental properties, the engineer is confronted with the question: "Just what fundamental property must I investigate to lay the basis for my analysis of this particular application?" Too often has he been misled into basing his analysis upon a property fundamental enough in nature but useless to his purpose.

2 The machine should provide for the investigation of all values of range ratio. (The range ratio is defined as the ratio of minimum stress to maximum stress in a loading cycle.)

3 The machine should be simple to operate and should be easily adaptable to the geometry and size of a wide variety of structural samples.

4 The apparatus should provide for accurate determination, control, and stability of the loading. This enhances the validity of the data and reduces test scatter. The necessity for frequent monitoring during testing is undesirable and such a condition decreases the value and usefulness of any fatigue-testing machine.

A discussion of some of the more commonly used fatigue-testing methods will emphasize the seriousness of certain inherent limitations. One widely known and used fatigue machine is the rotating-beam type, in which the stress in the specimen is a maximum at the surface and zero at the neutral axis of bending, this condition being obtained by the rotation of a transversely loaded cylindrical specimen. While this type of test provides data pertinent to the design of rotating shafts, which undergo the type of loading the machine imposes, it fails to provide data which may be accurately correlated with other loading conditions. Only completely reversed stresses may be imposed, and the machine is not adaptable to a variety of specimen shapes. Furthermore, since only a small surface band of material is subjected to the maximum stress, greater test scatter may be expected. This is true because no material is perfectly homogeneous, and it is statistically unlikely that as representative a sample of a material will be obtained in a small volume as in a large volume. It must also be borne in mind in the use of this type of data, that after any plastic flow whatsoever has occurred, the stresses in a bending-test specimen are not as calculated by the use of the classical bending formula.

Another commonly used apparatus is a sheet-fatigue-testing machine which applies a constant bending amplitude to a thin bar or sheet. The limitations of the data obtained from such a

[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

Presented at the Aviation Divison Meeting, University of California, Los Angeles, Calif., June 5–9, 1944, of The American Society of Mechanical Engineers.

test again spring from the limitations of the flexural formula which is used to calculate the stresses imposed. This formula is precise only for small deflections of straight beams whose width is of the same order of magnitude as the depth, and is subject to large errors when applied to a thin sheet at high bending displacements, or again when the surface stress exceeds the proportional limit of the material (2, 3). This type of machine is adaptable for testing at different values of range ratio. However, it has the limitation, characteristic of all constant-displacement machines, that constant displacement does not result in constant load for specimens which are subject to creep, to progressive elongation, or to change in elastic modulus during the course of a test. In this connection, it must be emphasized that, since many plastic materials are subject to these phenomena, we feel that the A.S.T.M. tentative specification for fatigue testing of plastics (4) is unsatisfactory for basic material tests, because it proposes this testing method. These limitations are particularly serious when a basically nonhomogeneous material such as laminated sheet is tested in such a machine. In such a case, the results are virtually worthless for obtaining design data for use on stressed-skin structures, since in structural laminates the filler material furnishes nearly the entire tensile strength, while the unit tensile load it carries in bending can only be roughly approximated.

Bending tests in general, after any plastic flow has occurred, tend to relate to the modulus of rupture of the specimen tested rather than to the ultimate strength of the material. This makes for a definition of failure which is artificial and which depends upon the specimen's geometry. The Forest Products Laboratory (5) has emphasized some of the difficulties involved in the application of the results of such tests.

From the foregoing discussion, it may be concluded that basic fatigue tests of a material generally should be direct tension-compression tests, since this manner of loading relates directly to the most basic and useful of all static material tests, namely, the tension test. Because of its more fundamental nature, the data from such tests may be used more readily than any other in developing methods of structural analysis. Furthermore, since a large portion of the aircraft structure is of the stressed-skin type, to which tension-compression data are directly applicable, apparatus for obtaining such data is also suitable for many tests of airplane structural components.

The design of a tension-compression-type machine offers two distinct possibilities, i.e., the use of a controlled load or a controlled displacement. The controlled-displacement type has certain practical advantages, since the loads may not only be determined by direct measurement but also, within the elastic limit, by the displacement. However, as disadvantages, its capacity is a function of both load and displacement, its power requirements are high, and at high speeds its operation and load control are complicated by inertia effects. The controlled-load type in itself includes a wide range of design possibilities, and therein lie many of its advantages, since it is inherently quite versatile. It may be driven by a rotating eccentric weight, by direct magnetic excitation, or by an inertia solenoid; it may be tuned to magnify the applied force and thus greatly reduce its power requirements, or it may be driven entirely off resonance. Its capacity is practically independent of displacement, and it is basically much simpler mechanically than the controlled-displacement-type machine.

LOCKHEED FATIGUE MACHINES

The Lockheed fatigue machines are of the controlled-load type, using inertia force with resonance magnification, and consist basically of the parts shown schematically in Fig. 1. Contrary to the usual practice with resonance-type machines, the operation is at constant speed and the vibrating system is tuned to resonate somewhat above the testing speed in order to obtain load control which is not severely affected by slight changes in speed or in specimen damping. Fig. 2 is a typical resonance curve showing the varying load applied to a specimen as a function of driving frequency. The operating speed employed is 1800 cycles per min and, for the case in Fig. 2, the amplification factor at this speed is 10. Usually the vibrating system is tuned to yield an amplification factor of between 5 and 50, depending upon the type of specimen and the range of load required.

Construction of Machines. At the present time two sizes of fatigue machines are used at Lockheed, the small or 10,000-lb-capacity machine and the large or 50,000-lb-capacity machine. The physical layout of these machines is shown in Figs. 3 and 5. The principal advantage of this type of construction is its versatility; it can be set up very easily to accommodate a wide

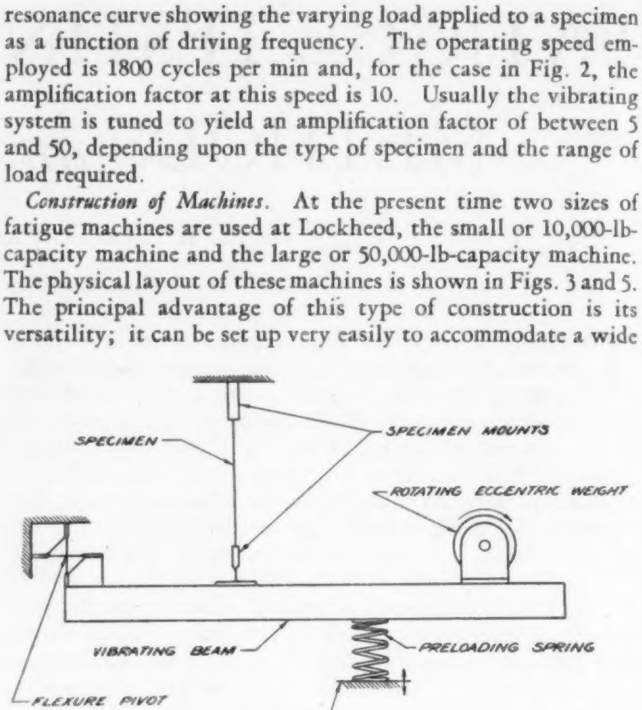

FIG. 1 SCHEMATIC SKETCH OF LOCKHEED FATIGUE MACHINES

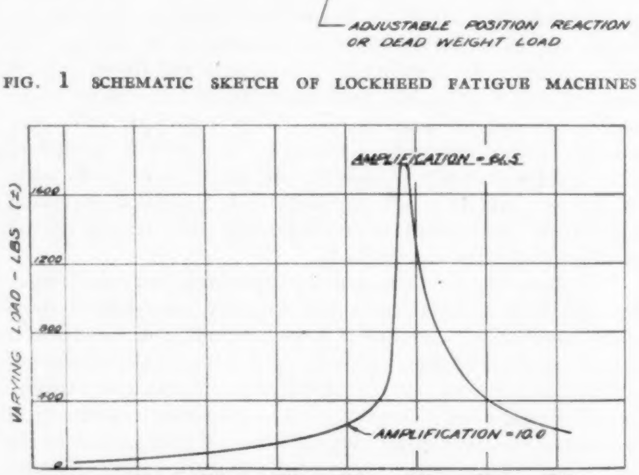

FIG. 2 TYPICAL RESONANCE CURVE SHOWING VARYING LOAD APPLIED TO SPECIMEN AS A FUNCTION OF DRIVING FREQUENCY

variety of specimen sizes and shapes. The frame structure is built entirely of standard structural steel. In the small machines, the horizontal frame members act as continuous rails so that the driving motor and the pivot may be easily adjusted to any position required to tune the vibrating system correctly.

Mounting Difficulties. Considerable trouble was experienced in obtaining proper mounting for these machines, since the frame weight is small compared to their varying load capacity, and high frame accelerations were produced. The first small machines were mounted on rubber pads, and while this mounting sometimes resulted in frame amplitudes greater than those of the vibrating beam, it was fairly satisfactory for low varying loads. However, when it was found that machines had a tendency to travel during a high-load test, they were bolted solidly to the floor. While results of this move were satisfactory from the standpoint of the operation of a single machine, beats between machines in some cases caused significant loading variations, and when the operation of the lathes in an adjacent machine shop was adversely affected, this mounting was discontinued. A more satisfactory mounting method was to put

hollow legs on the machines and to fill the hollow legs with lead shot, after which the whole assembly was mounted on rubber pads. The lead shot effectively increased the mass of the machines, and at the same time acted as a fairly efficient coulomb damper. The method used at present, as illustrated in Fig. 4, is to bolt each machine to an individual 10,000-lb reinforced-concrete block and to mount the block on rubber pads which are soft enough to give the assembly a natural frequency of less than 200 cycles per min, thus effectively isolating the machines from the floor and from each other. This method has proved to be completely satisfactory.

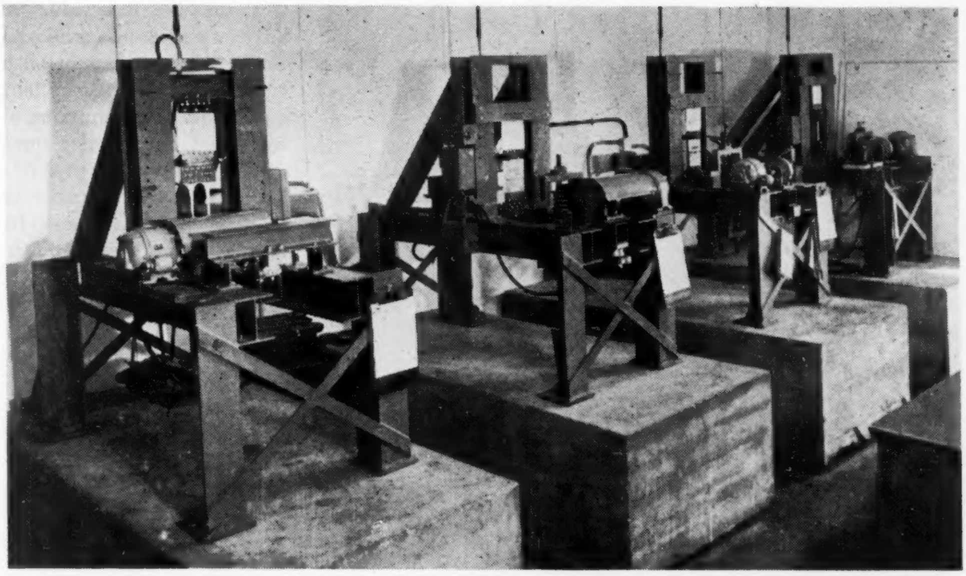

FIG. 4 GROUP OF SMALL FATIGUE MACHINES TESTING THE FOLLOWING TYPES OF SPECIMENS, LEFT TO RIGHT: PLASTIC SHEET MATERIAL, TWO TYPES OF RIVETED JOINTS, AND PERFORATED SHEET

Driving Units. The small machines are driven by rotating eccentric weights such as the one shown in Fig. 6. These consist of two unbalanced disks which may be rotated with respect to each other to provide continuous adjustment between 0 and 5.5 in-lb unbalance.

The vibrating beam is made of standard 4-in-sq steel tubing. Both the eccentric weight and the lower specimen mount are clamped to the beam instead of being permanently attached in order to facilitate changes in setup.

Pivots. Fig. 7 shows the flexure pivot used to connect the vibrating beam to the frame. Originally, a shaft and journals were used to pivot the vibrating beam, but the machine was then very noisy and a great deal of load instability resulted from changes in the bearing clearance and the consequent varying restraint offered by such pivots. The flexure pivots have eliminated this source of error entirely, and the machines are now practically noiseless in operation.

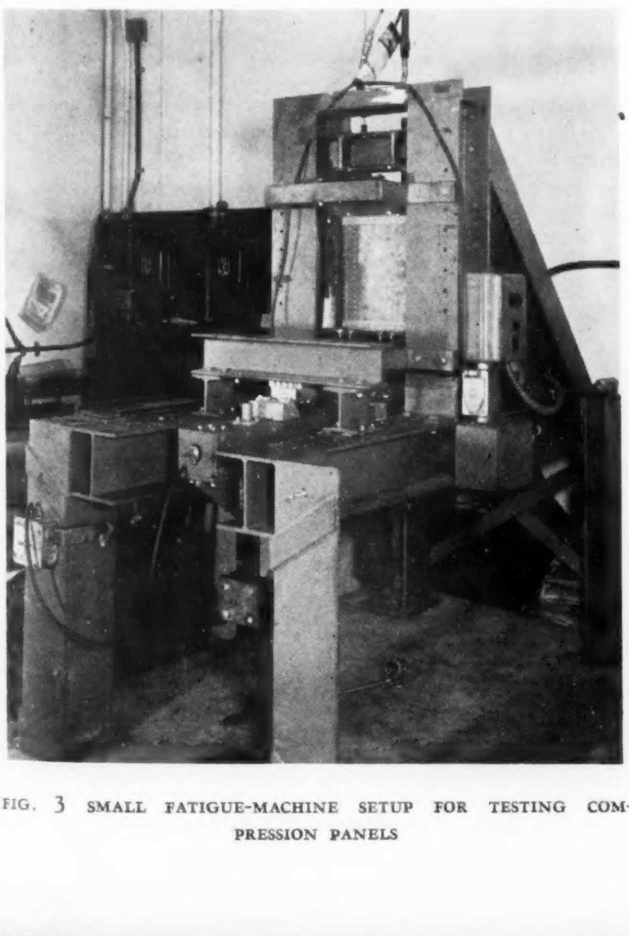

FIG. 3 SMALL FATIGUE-MACHINE SETUP FOR TESTING COMPRESSION PANELS

Resonance Tuning. When a machine is arranged to accommodate a particular kind of specimen, the distance from the pivot to the specimen mount is set so that the system will resonate well above the testing speed. Then sufficient mass is clamped to the vibrating beam to lower the resonant frequency to a value at which the required varying loads may be obtained easily with the available driving force, the tuning thus requiring only a few minutes' time. A Frahm vibrating-reed tachometer is used to determine the resonant frequency. Since the subresonance testing procedure allows a tolerance of several hundred cycles per minute in the resonance frequency of the system, it allows a wide variation in the deflection characteristics of individual specimens without requiring further tuning.

DYNAMIC LOAD CONTROL

The following four basic methods of dynamic load control may be used, singly or in combination: (1) Variation of the driving force; (2) variation of driving frequency; (3) variation of the natural frequency of the vibrating system; and (4) variation of the natural frequency of a secondary vibrating system coupled to the primary system.

Method 1, the variation of the driving force, may be accomplished by changing the amount of the eccentric weight. This method of load control, when used with a manually adjusted eccentric weight, is probably the cheapest system possible as regards initial cost, and is often satisfactory, but possesses the disadvantage that the test must be stopped while load adjustments are being made. This is particularly objectionable in the case of some types of specimens (notably of plastic materials) whose load deflection and damping characteristics radically change while dynamic tests are in progress, thus necessitating frequent small load adjustments. For this reason, to eliminate lost time, it is advantageous to have some means of adjusting the load without stopping the machine. Satisfactory systems for changing eccentric-weight unbalance while the machine is operating are generally quite complicated mechanically and increase both construction and maintenance costs. Nevertheless, if the machine is otherwise expensive, certain additional costs may be warranted, and such a system is used in controlling the load on the 50,000-lb-

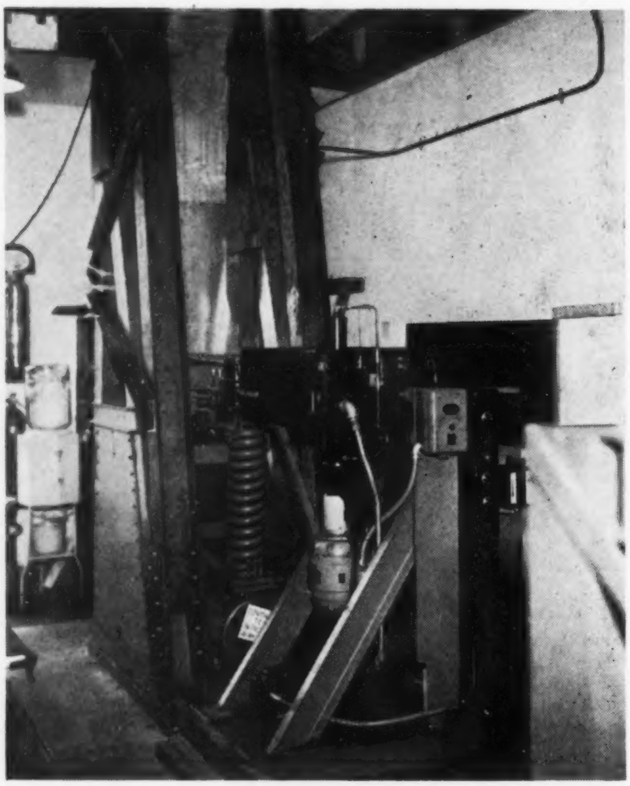

FIG. 5 LARGE FATIGUE MACHINE TESTING AN ACTUAL AIRPLANE-WING JOINT

capacity machine shown in Fig. 5. On this machine, two pairs of eccentric weights furnish the driving force, each pair being oppositely rotated to cancel lateral loading components. The phase relationship between the pairs can be adjusted by a differential mechanism while the machine is operating, continuous load control thus being provided. While this mechanism is functionally quite satisfactory, it is too expensive to be justified on the smaller machines.

Method 2, the variation of driving frequency, may be accomplished by the use of a direct-current motor driven from a motor generator set. This method is also expensive if accurate load control is to be maintained, since very accurate frequency control is imperative. For this reason, we use a variable-speed driving motor only in conjunction with tests which for some other reason require constant attendance.

Methods 3 and 4, based upon resonance tuning, in general are unsuitable for primary-load control, but are excellent for load adjustment when used in conjunction with some coarser means of approximating the varying load. Method 3, the variation of the natural frequency of the primary vibrating system, is probably most easily accomplished by changing the mass moment of inertia of the vibrating beam. It can also be accomplished by changing the spring rate, but in practice it is difficult to change the spring rate without likewise changing the static preload. Much more practical is method 4, the adjustment of the natural frequency of a small auxiliary system which is coupled to the vibrating beam. This method provides as wide a range of load adjustment as method 3 and uses a much smaller controlling system.

Fig. 8 shows such a mechanism coupled to one of the small Lockheed machines. It is, in essence, an adjustable Frahm-type vibration absorber, except that it is tuned to operate in phase with the testing-machine beam, and thus to increase, instead of absorb, the varying load. Attached to the vibrating beam at the pivot, this mechanism consists of a small weighted cantilever spring whose length can be adjusted over a sufficient range to change its resonant frequency from the testing speed to about twice that value. When the resonant frequency of this auxiliary system is well above the testing speed, there is practically no relative motion between it and the testing-machine beam, but as the spring length is increased, allowing the resonant frequency of the control mechanism to approach the testing frequency, the angular amplitude of the spring and weight becomes greater than that of the testing-machine beam, and the load on the test specimen is amplified. The control unit is so small in comparison with the primary vibrating system that its tuning has little effect on the tuning of the primary system, yet its capacity is sufficient to provide adequate load control when used in conjunction with a manually adjustable eccentric weight.

In use, the testing machine is set to apply from 50 to 90 per cent of the required varying load with the control unit detuned; then the auxiliary system is adjusted to supply the remainder of the varying load. In Fig. 10, the amplification factor of the

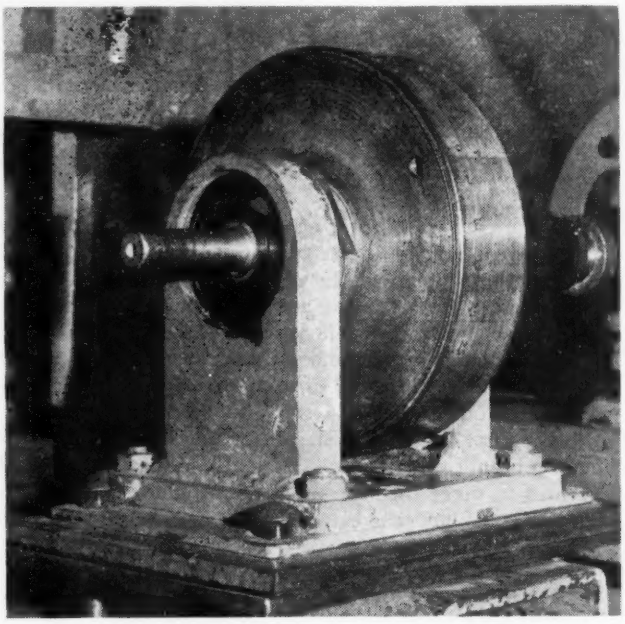

FIG. 6 MANUALLY ADJUSTABLE ECCENTRIC WEIGHT USED TO DRIVE SMALL FATIGUE MACHINES

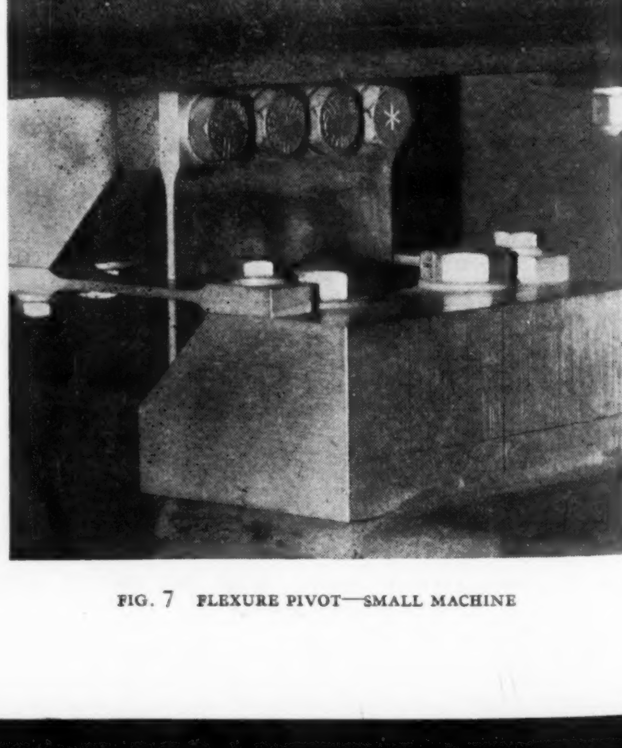

FIG. 7 FLEXURE PIVOT—SMALL MACHINE

auxiliary unit is plotted as a function of the change in spring length. This load amplification is applied to whatever initial load the primary system alone is supplying, and it may be noted that the sensitivity of control can be adjusted as desired by changing the load initially applied by the testing machine. The particular unit illustrated is adjusted by a $^1/_{50}$-hp electric motor.

Methods of Varying Range Ratio. In an inertia-driven system, the range ratio can be varied by applying a static preload, the dynamic load operating with this preload as a mean. In our testing, we preload the specimen either by applying a spring force or a dead-weight load to the specimen. The first method has the advantage of ease of control and also facilitates resonance tuning, since interchangeable springs having different spring rates may be used. However, for testing specimens which are subject to creep, or to progressive elongation, a spring-applied preload can be held constant only by continuous monitoring, and for such tests we have found the dead-weight method to be better. In using the latter method the dead weight is softly coupled to instead of being clamped on the vibrating beam to eliminate its inertia effect. The principal disadvantage of the dead-weight method is that it creates a different kind of fatigue, known as operator fatigue, but this disadvantage is often outweighed by the fact that only the varying component of the load need be checked during a test.

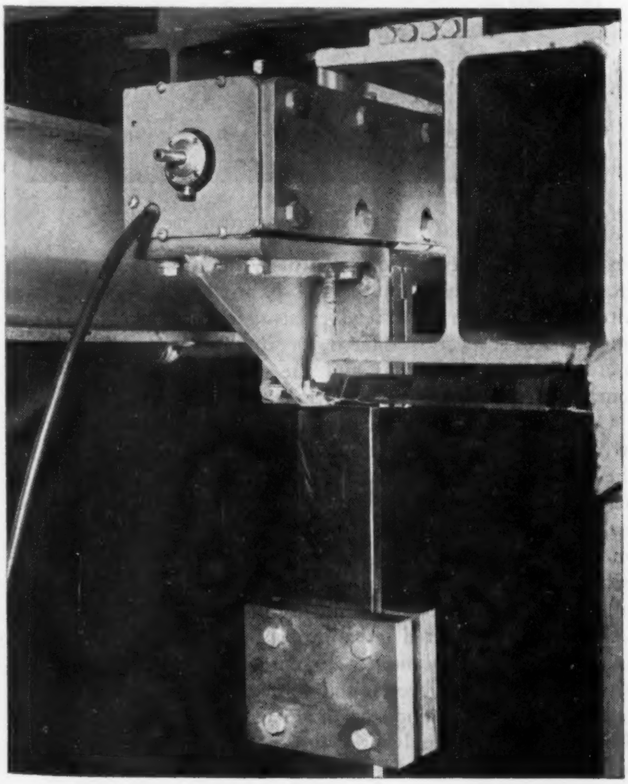

FIG. 8 AUXILIARY LOAD-ADJUSTMENT SYSTEM ON SMALL FATIGUE MACHINE

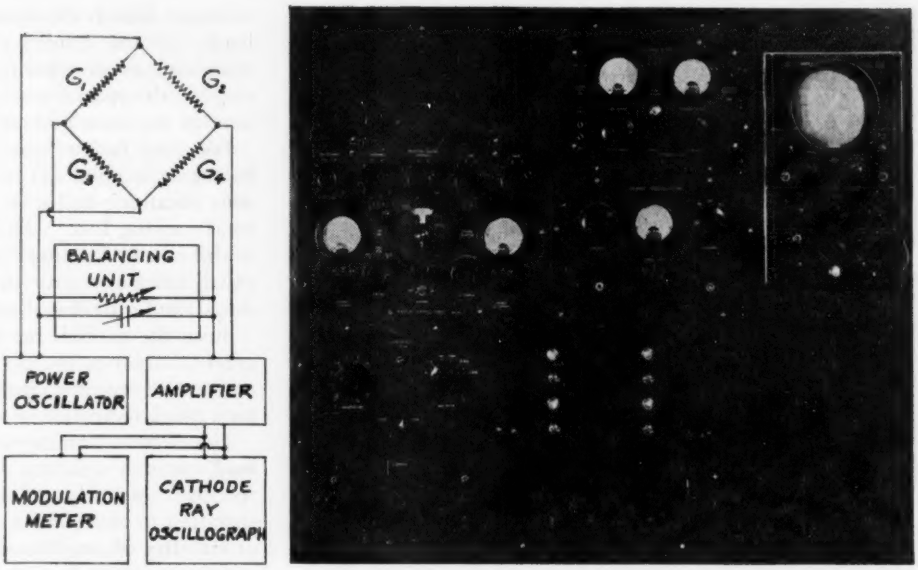

FIG. 9 DIAGRAMMATIC SKETCH AND ILLUSTRATION OF ELECTRICAL LOAD-MEASURING INSTRUMENTS

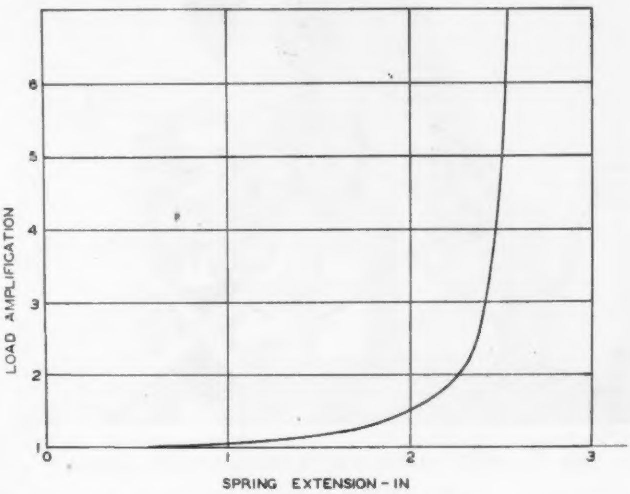

FIG. 10 LOAD AMPLIFICATION VERSUS SPRING LENGTH FOR AUXILIARY CONTROL MECHANISM

Measurement of Dynamic Loading. A very accurate and dependable means of measuring dynamic loads is to install electric-resistance strain gages to measure the dynamic strains in a specimen mount or other member which carries the load in series with the test specimen. By measuring the strains in such a member, all question of correct determination of the center of percussion is eliminated, and the strain measurements can be made directly proportional to specimen load, regardless of the speed of testing or of the dynamic characteristics of the vibrating system. We employ this method almost exclusively in our dynamic testing and believe it to be superior to available mechanical or optical methods, since inertia and friction effects are eliminated, and since such high sensitivity may be obtained with available electrical measuring instruments that the same load-measuring member may be used with adequate accuracy over a very wide range of loads.

One particular advantage of this method is that it makes possible not only the measurement of the maximum and minimum loads in a loading cycle, but also the determination of the entire loading cycle as a function of time. Furthermore, by the use of an additional circuit whose output is proportional to specimen strain, the dynamic load-strain relationships for any test specimen may be plotted electrically on the screen of a

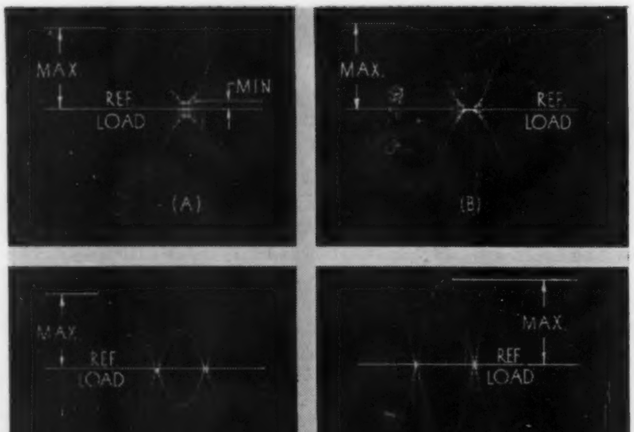

FIG. 11 TYPICAL OSCILLOSCOPE RECORDS FOR VARIOUS REFERENCE-LOAD POSITIONS

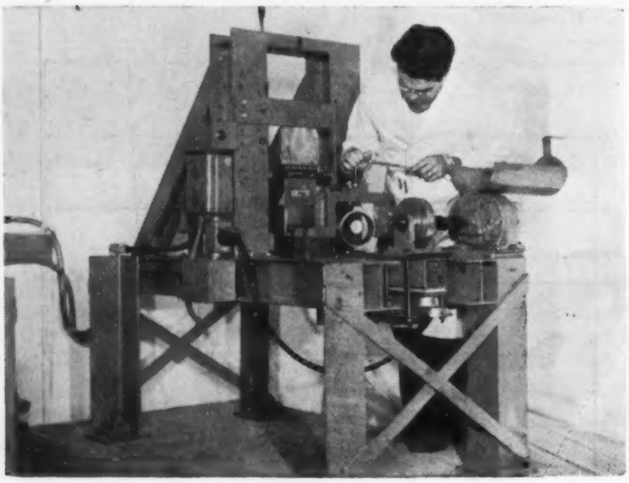

FIG. 12 LOAD CALIBRATION OF SMALL FATIGUE MACHINE

cathode-ray oscillograph. Such information is often of great importance in analyzing test results.

Fig. 9 shows our most commonly used electrical measuring system. The load-sensitive element consists of an electric-strain-gage bridge, G_1, G_2, G_3, and G_4, cemented to the load-measuring member. Two opposite gages (say G_1 and G_3) are oriented in the direction of load and the other two gages are placed in diametrical opposition on the same member to compensate for temperature changes. This bridge is used to modulate the amplitude of a carrier wave supplied by the power oscillator; it is balanced at a physically known specimen load (by means of the decade resistors and variable capacitors), and its output amplitude is proportional to the difference between the arbitrary zero load and the applied load. Hence we have an electric current or potential which is proportional to specimen load and which may be measured directly or electrically plotted against time or against specimen strain on a cathode-ray oscillograph.

The per cent of modulation meter is designed to measure maximum and minimum values of voltage with respect to any particular reference point at which the bridge is balanced. The records, shown in Fig. 11, indicate the load values which may be determined with this instrument for each of four different balancing positions: (*a*) The general case when both the maximum and minimum loads have the same sign with respect to the reference load; (*b*) a special case of (*a*) when the reference load is the same as the minimum load or maximum load; (*c*) the general case when the maximum and minimum loads are of opposite sign with respect to the reference load; and (*d*) the special case of (*c*) when the reference load is the same as the static preload for sinusoidal dynamic loading.

For most fatigue tests, sinusoidal loading is obtained, and balancing method (*d*) is used for determining dynamic loads, thus obtaining full-scale meter deflection for one half of the total varying load. The correct static preload is maintained in this case by keeping the maximum and minimum wave peaks equal, since any error in static preload will result in a wave shape similar to that shown in Fig. 11 (*c*).

Since the cathode-ray oscillograph cannot be read with as great accuracy as the per cent of modulation meter, it is ordinarily used only for visual inspection of the loading cycle, and for a quick indication of static preload.

The electrical measuring system is usually calibrated against load for each specimen by applying the correct loads to the specimen statically and measuring the bridge unbalance corresponding to those loads. This procedure eliminates questions of stability of amplification and also obviates the necessity of a rather complicated general calibration which would include the change in strain sensitivity of the bridge due to changes in the balancing resistance. The static calibration loads are applied with an accurate compression dynamometer, shown in Fig. 12.

TYPICAL TEST RESULTS

The scope of research and testing that can be accomplished by means of this technique is wide. And although many fields are yet to be explored and much information is yet to be obtained, the incorporation in this paper of a few charts, photographs, and curves should afford an opportunity to evaluate a representative sampling of what has been done. Presented are illustrations of basic data upon which a rational analysis for life expectancy may be founded, and of the results obtained by testing some structural components. Such data, in combination with static test results and photoelastic analysis, have already been used to extend existing theory. Generally, an optimistic prospect is offered for the future development of useful empirical formulas and the substantiation of the currently developing analytical fatigue-strength theory.

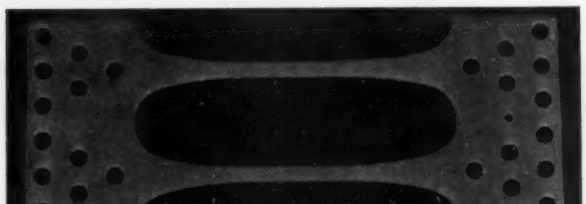

FIG. 13 SHEET-MATERIAL FATIGUE SPECIMEN

Of great basic importance is the establishment of the fatigue strength of commonly used aircraft materials. Fig. 13 shows the test specimen used by Lockheed to obtain such data on sheet materials. This specimen has been used in obtaining material properties of aluminum alloys, steels, and plastics. The double-specimen design was developed to obtain even loading distribution over the cross section, since the two legs can be easily adjusted to the same tension during installation.

A single-row riveted lap joint, shown installed in Fig. 12, does not in itself simulate a complete airplane attachment. Nevertheless, it has been found very useful for providing basic data to be used in connection with general fatigue-strength theory and in the analysis of more complex structures which can rarely be tested directly. It is most valuable when used for comparative purposes in connection with newly developed materials and processes. Such a specimen, for instance, was used to study the effect of rivet spacing upon fatigue strength,

and the results not only provided the answer to the original problem, but also brought out the striking correspondence which exists between photoelastically determined stress-concentration factors and those established by fatigue analysis (6). On several occasions, when new materials have been recommended for use, the riveted joint, manufactured from these materials and tested in fatigue, provided an excellent means of comparing the strength characteristics of the new material with those already being used.

To emphasize the versatility of these testing methods, attention is called to the arrangements already illustrated in Figs. 3, 4, 5, and 12. In the small machines, specimens have been tested with spring rates varying between 3500 lb per in. for steel aircraft cable to 330,000 lb per in. for compression panels. Although, as has been pointed out before, most aircraft application involves testing in tension or compression, the machines are easily adapted to apply other types of loading. For instance, steel and aluminum castings have been tested in bending and bolts have been tested in shear. Fig. 14 illustrates an arrangement for this latter type of test.

To illustrate typical results several curves are presented. Fig. 15 is an S-N curve for Alclad 24S-T sheet at the range ratio of 0.2. Fig. 16 is a family of S-N curves for a single-row riveted lap joint. Fig. 17 illustrates typical results on the type of compression panel shown installed in Fig. 3, for a range ratio of 5.

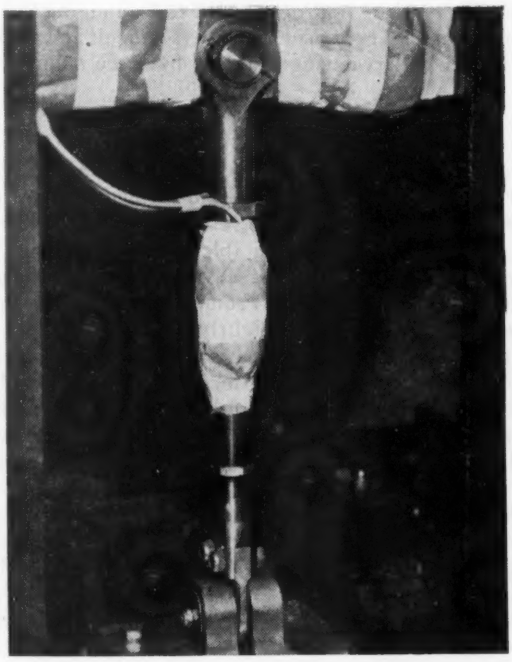

FIG. 14 SHEAR-BOLT FATIGUE-TEST ARRANGEMENT

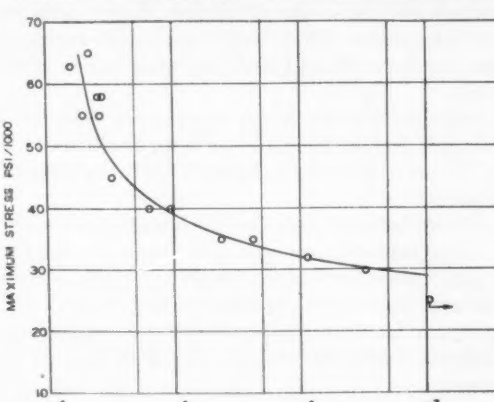

FIG. 15 S-N CURVE 24S-T ALCLAD AT $R = 0.2$

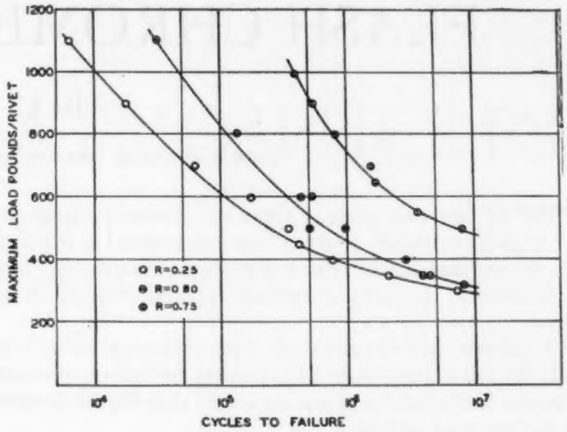

FIG. 16 S-N CURVES FOR 0.064 24S-T ALCLAD SINGLE-ROW RIVETED LAP JOINT AN430-DD-6 RIVETS AT 1-IN. SPACING

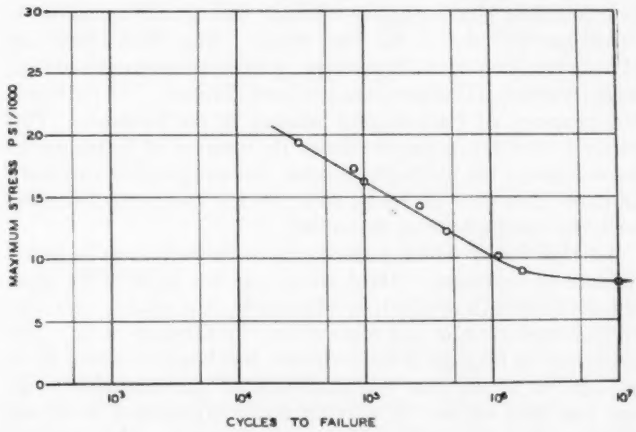

FIG. 17 TYPICAL S-N CURVE FOR COMPRESSION PANEL, FIG. 3

CONCLUSION

Some of the more important considerations in the general design of fatigue-testing apparatus, and the methods and equipment developed and presently used at the Lockheed Aircraft Corporation, have been discussed in some detail. Since it is the conviction of the authors that these methods and equipment are well suited for aeronautical research and testing, emphasis has been placed upon their advantages. It must not be inferred from this, however, that the authors are not aware that room for further improvement exists. On the contrary, constant endeavor is being made to improve both the machines and the techniques further.

ACKNOWLEDGMENT

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BIBLIOGRAPHY

1 "The Control of Life Expectancy in Airplane Structures," by R. B. Bland and P. E. Sandorff, *Aeronautical Engineering Review*, vol. 2, Aug., 1943, pp. 7, 9, 11, 13, 15, 16, 21.

2 "Fatigue Tests as a Means of Evaluating Corrosion Damage of Sheet Metals," by W. H. Mutchler and J. A. Kies, Proceedings of the A.S.T.M., vol. 42, 1942; discussion of paper by W. N. Findley, p. 574.

3 "Strength of Materials," by S. Timoshenko, second edition, D. Van Nostrand Company, Inc., New York, N. Y., 1940, pp. 88-89.

4 "Tentative Method of Test for Repeated Flexural Stress (Fatigue) of Plastics," (D671-42T), A.S.T.M. Standards, 1942, part 3, p. 1251.

5 "The Fatigue Behavior of Wood and Plywood Subjected to Repeated and Reversed Bending Stresses," U. S. Forest Products Laboratory, Report No. 1327, Oct., 1943.

6 "Effect of Rivet Pitch on the Fatigue Strength of 0.025-0.025 Alclad 24S-T Riveted Joints," by Victor Seliger, N.A.C.A. Technical Note No. 900, July, 1943.

FLASH CHROME PLATING TO SIZE

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THERE are two general types of chrome plating. One type is commonly referred to as ornamental or decorative chrome and is that which is applied to automobile bumpers, hardware, household appliances, and articles of that nature.

The process usually involves copper-plating on the base metal; nickel-plating over the copper; polishing the nickel to a mirror finish; and then plating a very thin film of chromium over the polished surface.

HARD-CHROME PLATING

The other type of chrome plating is known as hard chrome and involves electroplating a more substantial quantity of chromium directly on the base metal. Since flash chromium plating is a form of the latter type, we shall consider briefly the most interesting characteristics of hard chrome. The outstanding property of hard-chrome plating is its hardness. This varies somewhat in proportion to the amount of hydrogen involved during the plating operation, but a typical deposit has a hardness of 8 to 9 on Mohs scale, which compares favorably with that of hard-facing materials.

Another factor which contributes to its usefulness is its resistance to corrosion. Hard chrome is not affected by most organic chemicals or alkalies. However, it is readily attacked by hydrochloric acid and more slowly by sulphuric acid. The coefficient of friction of hard chrome has been estimated as 30 per cent to 50 per cent less than that of steel and this property has been utilized in solving many engineering problems in which hardness and corrosion resistance are relatively unimportant compared to the necessity of reducing friction to a minimum. Chromium melts at 2939 F and retains a bright surface up to approximately 900 F. It is nonmagnetic and has relatively low heat and electrical conductivities.

Perhaps the most serious disadvantage of hard chrome is its extreme brittleness. It is not advisable to use it, particularly in heavy deposits, where there is danger of impact or where it is subjected to heavy compression loading on small areas. The brittleness can be reduced to some extent by heating to a temperature of 300 to 400 F for 3 hr, but this treatment reduces the hardness somewhat through the evolution of hydrogen.

The thickness of hard-chrome deposits varies from 0.0001 to 0.050 in. depending upon the purpose for which it is used. Thicknesses of 0.010 or more are used in the salvage of worn parts. Deposits of 0.006 to 0.010 are frequently used on new parts which are to be subjected to unusual abrasive or corrosive conditions. Most commonly used are films having a thickness of from 0.002 to 0.006. These provide adequate resistance to wear and corrosion for most purposes and have proved economical from the standpoint of not requiring an excessive amount of grinding stock as to the heavier deposits.

FLASH PLATING PROCESS

Flash chrome plating is the term applied to deposits of 0.001 or less. Parts which are so plated are not ground after plating, although they are frequently lapped, honed, or buffed to provide the required finish. In any case, it is necessary to control the amount of deposit. This is accomplished through careful control of plating time, solution content, temperature, and current density. Tolerances equal to one tenth of the plating thickness can be maintained

Since any imperfection in the surface of the base metal is magnified in plating, it is necessary to exercise great care in the preparation of the surface before flash-plating. After being ground, wheel marks should be completely removed before plating. This is most often accomplished by buffing, but in cases where true cylindrical form must be maintained, lapping or honing is sometimes used.

A study of the purposes for which flash chrome is now being used indicates that either low friction or corrosion resistance, or both, are desired. Frequently flash chrome is used to accomplish one result, and it develops that some other benefit is derived. For instance, an oil-tool company manufactures a cone-shaped fitting which is used to install rubber drill-pipe protectors. In service these tools rusted and flash chrome was tried as a protection against corrosion. When put in service, the operator was amazed to discover that only a fraction of the customary pressure was required to force the rubber over the fitting. The result is that in addition to prolonging the life of the tool, its use has been made much less difficult and the breakage of rubber collars during assembly has been reduced 50 per cent.

APPLICATIONS TO CUTTING TOOLS

One of the most publicized uses of flash chrome is its application to cutting tools. Originally hard chrome was used to salvage worn tools, such as taps, drills, reamers, and forming tools. This did not prove profitable owing to grinding costs. However, it did indicate that advantages could be gained through flash-plating. It is now common practice to flash-plate new tools or those which are slightly worn.

The principal advantage gained is through reduction of friction. Plated tools do not pick up metal being worked and chips tend to slide off the tool surface without transferring their heat to the tool. In one instance, the life of chasing cutters was increased 10 times, cutting 3/4–20 threads in 4130 steel; similar results have been obtained with other cutting tools.

Flash chrome has been used successfully in increasing the size of standard drills, taps, and reamers to produce holes or threads which are slightly larger than standard sizes. It is possible to increase diameters by as much as 0.002 and still maintain close tolerances. This has often saved the cost of special tools.

One of the important uses of flash chrome is in metal stamping. Through the reduction of friction, better parts are produced with less rejects. The life of dies is greatly increased since the chrome can be replaced before any steel has been removed from the die.

Plastic and rubber molds frequently present problems due to the corrosive action of the material being molded or through adhesion. In most cases flash chrome avoids the difficulty and is widely used.

In the oil-tool industry flash chrome is finding favor for many purposes. One manufacturer uses this process on the threaded stems of gate valves to reduce friction and prevent corrosion. The cap screws used on the bonnets of large valves are flash-chrome-plated to facilitate their removal when repairs are necessary. Reciprocating-pump rods are plated to provide a better packing surface.

Flash chrome has not been used very extensively in hydraulic

(*Continued on page 728*)

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HEATING *of* STEEL *in* CONTROLLED ATMOSPHERES

By SAM TOUR

SAM TOUR & CO., INC., NEW YORK, N. Y.

THIS review of the development and status of the art of heating steel in controlled atmospheres traces the development for a period of approximately 30 years, beginning just prior to the first world war. The chronological arrangement is broken down into the periods of basic research, adaptation to practice, general acceptance and modern trends, and modern equipment.

BASIC RESEARCH

An outstanding and worth-while contribution to the basic knowledge required to develop the art of heating steel in controlled atmospheres was made in 1915 by A. H. White and H. T. Hood (1).[1] These investigators studied and reported upon the burning of mixtures rich in gas and lean in air in a heated muffle, for the purpose of heating steel without excessive scaling or decarburization. They pointed out that a neutral atmosphere is produced when approximately 1 volume of illuminating gas is combined with 2 volumes of air; a mixture so rich that it will not burn unless preheated. They further pointed out that this atmosphere, although neutral to iron, decarburizes steel slowly at forging temperatures.

It is somewhat unfortunate that almost thirteen years were to elapse before this basic principle was to be applied in practice to a commercial furnace.

In 1921, Lellep (2) published data and information showing that certain atmospheres may scale one metal and not another metal. These observations were soon followed by a paper in 1922, by G. C. McCormick (3). At about the same time, Dickenson (4) presented a paper in which it was shown that scaling of steel varies with temperature and with the carbon content of the steel.

Basic research in connection with carburization and decarburization of steel was pursued in the period from 1922 to 1928 and is demonstrated by the valuable work of Sykes (5). In this work, Sykes showed that the gas mixture necessary to secure carburizing varies with the carbon content of the steel. R. G. Guthrie and O. Wozasek (6) presented further results of valuable basic research. In this contribution they showed that perfectly dry raw gas was a poor carburizer of steel, but that with a small and controlled percentage of water vapor it became an active carburizer. J. J. Curran and J. H. G. Williams (7) demonstrated the rapid rate of decarburization of high-carbon steel which can and often does take place in reducing atmospheres.

A number of other valuable contributions during this period were contained in the work of Murphy and Jominy on scaling in atmospheres containing carbon dioxide and water vapor, and by Eastman and Evans on carburizing and decarburizing, and by Pring and Fairlee on carburizing with methane and hydrogen.

Before, during, and after the first world war, the problem of how to heat steels without packing and without scaling was continually before industry. No satisfactory answer had been found which could be applied to the commercial heat-treatment of even small tools.

ADAPTATION TO PRACTICE

At the Metal Congress in 1928, under the auspices of the American Society for Steel Treating, there was demonstrated the first commercial furnace for the practical heat-treatment of tools without scaling or decarburization. C. I. Hayes, Inc., of Providence, R. I., demonstrated a new furnace called the "Certain Curtain Furnace." This furnace had a built-in atmosphere generator in accordance with patent No. 1, 724,583 which was issued to C. I. Hayes on August 13, 1929. The application of this furnace to industry was described shortly after that time by the present author (8). Small intricate tools of high-speed steel were heat-treated in controlled atmospheres and showed no evidence of scaling, pitting, carburization, or decarburization.

Jominy (9), in 1931, showed that perfectly dry hydrogen was neutral to steel at temperatures up to 1600 or 1700 F, but, with as little as 0.1 per cent of water vapor, became an active decarburizer toward steel even at temperatures as low as 1200 to 1300 F. This was a worth-while contribution and confirmed the importance of avoiding wet atmospheres containing hydrogen for the heat-treatment of carbon tool steels.

The application of the principles, described by Jominy in 1931, to practice in the heat-treatment of carbon tool steels was demonstrated by the author (10) in 1932, in a paper in which the importance of water-vapor content of the furnace atmosphere was stressed and suitable atmospheres were described for different types of steel. For practical purposes, this paper classified furnaces in two groups, (*a*) as those with transient or rapidly moving atmospheres, and (*b*) those with quiescent or very slowly moving atmospheres. It was stressed that quiescent-atmosphere furnaces offered less danger of reactive gases getting to the steel to do damage than was the case in transient- or moving-atmosphere furnaces.

In 1933, N. R. Stansel (11) correlated considerable of the work done up to that time and presented the information in usable chart form. This has been a worth-while reference book for all those interested in the problem of heating steel in controlled atmospheres.

In the early 1930's, the problem of heavy scaling could be considered as having been brought under control for tools and die work and small parts. The main problem of avoiding soft skin as well as scale was being actively pursued. The problem of scale-free heating of large bodies of steel as for forging and rolling operations was not solved and remains substantially unsolved today.

GENERAL ACCEPTANCE

General acceptance by industry of controlled-atmosphere heat-treating came in the late 1930's. Numerous furnace companies entered the field. Many varieties of equipment became available and widely used. Furnaces with built-in furnace atmosphere generators using various types of fuel and various systems for generating and distributing the atmosphere within

[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

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the work chamber were developed. Numerous types of separate atmosphere generators were developed using various types or combinations of fuels to produce the desired atmosphere. B. W. Gonser (12) describes the various types of equipment and special atmospheres which were developed and available at that time.

In a 1940 paper, the author (13) stressed the fact that a quantity of water vapor existed in furnace atmospheres and demonstrated that there was great value in the operation of dehydrating and reheating the products of combustion for their use in furnaces for the heat-treatment of steel. This paper described the basic principle of "recirculation." The products of combustion of the rich gas-air mixtures are drawn out of the combustion chamber through a cooler where the water vapor is condensed. Dehydrated gas is then pumped into a small reheating chamber within the furnace. In this reheating chamber the gases are brought up to furnace temperature, react among themselves to re-establish equilibrium, and then enter the furnace proper where they form the atmosphere surrounding the work being heat-treated. By putting the combustion chamber beneath a curtain slot at the entrance of the furnace and therefore inside of the furnace proper, it is possible to provide external heat for the combustion chamber and to operate the circulating pump at such a speed as to handle a larger volume of gases per hour than is being introduced through the burners. By doing this, a considerable amount of recirculation is obtained and a large quantity of the furnace gases may be used over and over again with the addition of some fresh products of combustion for each pass through the furnace.

A further development and application to practice at this time was shown by the author (14) in a paper which presented in detail the extreme importance of control of combustion-chamber temperature. It was demonstrated that the products of combustion of a given mixture of gas and air varied over a wide range with respect to hydrogen, carbon monoxide, and moisture content as the combustion-chamber temperature is varied. The limiting temperatures for successful operation of rich mixtures of gas with air for the production of gases for furnace atmospheres were given. Seven different possible methods were described for supplying heat to the combustion chamber of a gas-atmosphere generator, to accomplish successful production of suitable atmospheres for the heat-treatment of steel.

The general acceptance of controlled-atmosphere furnaces for the heat-treatment of steel was thoroughly acknowledged and demonstrated by the fact that the American Society for Metals held a symposium (15) on the subject in 1941, which was later published in book form.

MODERN TREND AND MODERN EQUIPMENT

At the present time, the modern trend is toward bright annealing and bright hardening. Even slight discoloration is being avoided in many cases. To accomplish this purpose, it is required that the atmosphere be highly reducing, that the material be cooled in the reducing atmosphere or quenched from the reducing atmosphere without being passed through the air. This type of bright annealing and bright hardening has resulted in the development of special furnaces for the purpose. Where surface discoloration but no decarburization is permitted, the very highly reducing atmospheres are not necessary and atmospheres similar to those described by the author (10) in 1932 may still be used.

BIBLIOGRAPHY

1 "The Heat Treatment of Iron and Steel in a Neutral Atmosphere," by A. H. White and H. T. Hood, *American Gas Light Journal*, vol. 103, Nov. 15, 1915, pp. 310-311 and 314-315.

2 "Scaling of Oxidation and Reduction of Metals in Fuel-Fired Furnaces," by O. Lellep, Trans. A.S.S.T., vol. 1, 1921, pp. 346-349.

3 "Furnace Atmospheres and Their Relation to the Formation of Scale," by G. C. McCormick, Trans. A.S.S.T., vol. 2, 1922, pp. 1006-1012.

4 "Note on the Scaling of Steels at Elevated Temperatures," by J. H. S. Dickenson, *Journal of the Iron and Steel Institute*, vol. 106, 1922, pp. 128-140.

5 "Carburizing Iron by Mixtures of Hydrogen and Methane," by W. P. Sykes, Trans. A.S.S.T., vol. 12, 1927, pp. 737-758.

6 "Gas Carburization of Steel," by R. G. Guthrie and O. Wozasek, Trans. A.S.S.T., vol. 12, 1927, pp. 853-870.

7 "Decarburization of High-Carbon Steel in 'Reducing' Atmospheres," by J. J. Curran and J. H. G. Williams, Trans. A.S.S.T., vol. 14, 1928, pp. 809-830.

8 "The Heat-Treatment of Delicate Tools of High-Speed Steel," by Sam Tour, *Fuels and Furnaces*, vol. 8, 1930, pp. 1251-1256, and 1258.

9 "Surface Decarburization of Steel at Heat-Treating Temperatures," by W. E. Jominy, Engineering Research Bulletin, No. 18, Department of Engineering Research, University of Michigan, March, 1931.

10 "Heat-Treating Furnace Atmospheres," by Sam Tour, *Metals and Alloys*, vol. 3, 1932, pp. 270-272.

11 "Industrial Electric Heating," by N. R. Stansel, John Wiley & Sons, Inc., New York, N. Y., 1933.

12 "The Status of Prepared Atmospheres in the Heat-Treatment of Steel," by B. W. Gonser, *Industrial Heating*, December, 1939.

13 "Water Vapor in Furnace Atmospheres," by Sam Tour, Trans. A.S.M., vol. 29, 1941, pp. 710-731.

14 "Furnace Atmosphere Generation," by Sam Tour, Trans. A.S.M., vol. 29, 1941, pp. 693-709.

15 "Symposium on Controlled Atmospheres," American Society for Metals, Cleveland, Ohio, 1941.

Flash Chrome Plating to Size

(Continued from page 726)

equipment for aircraft; howeve-, there is no reason why it should not in many instances replace heavier deposits which require grinding. One problem in this connection would be to obtain a perfect finish on the base metal without developing flat spots in buffing. This could probably be accomplished with either superfinishing or centerless buffing. Centerless buffing would also be indicated after plating.

FLASH CHROME EFFECTIVE AS GAGE FINISH

Hard chrome has been used on plug gages for perhaps 10 years. More recently, flash chrome has been found to be just as effective. Where very close tolerances are encountered, gages are lapped after plating with good results. The life of thread gages is indefinitely prolonged by grinding them to the low limit and plating to the high limit. When worn to the low limit they are replated.

There have been many important developments in the use of flash chrome on engine parts. Heavy deposits of chrome failed on camshaft lobes. Thicknesses of 0.0001 to 0.0003 in. have been very successful. Crankshafts have been flash-plated with good results as a means of reducing friction. There are two Continental truck engines in operation with cylinder walls plated to size. They have not been in service long enough to develop any definite results, but the engines are operating efficiently. Valve stems are flash-chrome-plated to reduce wear and eliminate sticking, and the surfaces under the heads have been successfully plated to prevent adherence of gummy deposits. An oil-producing company has had difficulty with carbon deposits in engine cylinder heads where casing-head gasoline is used. This condition has been corrected by flash-plating the heads.

There have, of course, been hundreds of other effective uses of flash chrome plating. There have also been some failures. Like so many other developments of the last decade, chrome plating, and particularly flash chrome plating is in its infancy. However, it is safe to conclude that flash chrome plating is worth a trial if it is desired to reduce friction, retard corrosion, or provide longer life for metal parts.

STEREOSCOPIC PHOTOGRAPHY

By JOHN T. RULE

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WHILE practically everyone is acquainted with stereoscopic photography in one form or another, to refresh the reader's memory on the basic principles of stereoscopic vision, I will state briefly the problem involved in order that he may have a clear understanding of what we are trying to accomplish.

Suppose one stood before a window without moving his head and closed the left eye. Then the right eye, if held still, could never be certain whether it was viewing a scene through the window or a perfect picture of the same scene on the window. Now if the left eye is opened and the right one closed, the same thing would be true. However, two interesting facts present themselves, (1) the picture seen by the right eye would be different from that seen by the left, and (2) it would overlap the same area. If the real scene were being viewed, each eye would see only its own picture, whereas if the pictures were being viewed, both eyes would see both pictures.

Now if each eye only sees its own picture, we naturally see it as in normal vision in three dimensions. In other words each eye receives a two-dimensional image. The brain interprets the differences between these two images in terms of depth. Consequently, the problem of stereoscopy is only this: To place the two proper pictures in the same place at the same time in such a way that each eye sees only the picture intended for it. Once this is done, the retinal image in each eye will be exactly the same as though the original scene were being viewed, and the brain will interpret it in exactly the same way.

FROM THE STEREOSCOPE TO THE POLARIZER

Originally there were two simultaneous efforts to do this; one by using mirrors, and the other by placing the pictures in the area near enough to the eyes so that the field of view had not yet started to overlap, and then enabling the eyes to focus at this short distance by means of lenses. This, of course, is the old parlor stereoscope. This had very obvious limitations, chief of which was the antisocial one of having to view a picture alone.

The next effort came from the desire to print. This was the so-called anaglyph in which the pictures were of different colors which were filtered through viewers of the same colors. Though this has grave defects, it has had some success in specific fields, notable in the printing of aerial photographs. I will mention only two defects of this method: (1) the difficulty of matching color filters to color dyes or inks without having a large percentage of the wrong wave lengths from the dyes pass through the filter and thus yield ghost images; (2) the obvious one, since color has been used to obtain the stereo, one cannot have colored stereos.

After this the art lay nearly dormant for a number of years waiting for the development of the obviously correct method, i.e., the use of polarized light. With the invention by E. H. Land of a polarizer that could be produced in quantity, the stereoscopic field immediately took on a new lease of life.

DEVELOPMENT OF THE VECTOGRAPH

The logical step was to project two pictures with polarizers in front of them, with axes perpendicular to each other, and to supply the audience with viewers similarly polarized. This double-projection method is still used exclusively when color is desired and is only gradually being superseded by the vectograph which enables us to use single instead of double projection.

With an eye to the movie industry, the avoidance of double projection, and the desire to have prints, the vectograph was developed by Mr. Land. This enables us to have two pictures in the same place at the same time without interference. Vectographs have the two pictures, one on either side of a special sheet. The pictures are polarized within themselves, do not interfere, and can be made either as slides or prints. They represent an entirely new kind of photography for they are not images in black and white but images in terms of per cent of polarization. We view them through viewers and obtain pictures which inherently can be as good as those of normal photography. Vectographs are being made in color in the laboratory but have not yet been released publicly. I believe it is impossible to overemphasize the revolutionary character of the vectograph or its importance in the photographic field.

Mention may be made at this point that one very good method for limited use exists which does not require viewers. Of much greater importance, however, is the fact that the vectograph can be printed. Vectograph slides can be projected by any ordinary projection equipment making no change whatever except the use of an aluminized screen which happens to be cheaper than the usual beaded screens.

Striking results have been obtained from using polarized light in stereoscopy. The presence of depth has a very powerful appeal. In fact, Oswald Spengler, the most magnificent exaggerator of our time, claims very convincingly that the feeling for depth—I think he probably would use the word yearning for depth—is the key symbol of western civilization. The reader can draw his own conclusions as to what he might mean by that. It is a fact, however, that a three-dimensional picture has a remarkably fresh and permanent appeal to all of us. Furthermore, there isn't the slightest doubt that it makes many complex and difficult-to-understand pictures very simple and understandable. The latter point is clearly shown by aerial photographs.

VECTOGRAPH A POWERFUL WAR TOOL

The vectograph has become a powerful tool in this war. The ability of a group of officers to analyze vectographs together, which is difficult in a stereoscope into which only one individual can look, is of enormous value strategically.

In photographing machinery and machine parts, three-dimensional pictures have great value. Many intricate mechanisms are very difficult to analyze in two dimensions. Depth levels of separate parts have to be explained verbally with varying success in two dimensions but are perfectly obvious in three. The third dimension has a "separation" value which is of great importance.

PROBLEMS OF STEREOSCOPIC PHOTOGRAPHY

The most interesting fact about stereoscopic photography is that the approximate size of the resultant image must be known before the pictures are taken. In ordinary photography, any size picture can be shown on any size screen. In stereoscopic photography, the distance between the two lenses, the interocular, is determined by the size of screen which is to be used or the size of print it is intended to make. In general we

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take three pictures of subjects such as these. These pictures will yield three pairs, one pair for making prints, the other two pairs for different size screens.

The wider the interocular that is used, the greater the depth that will be achieved for any given size image. To achieve a perfectly shaped image, the camera interocular dictates both the size of the resultant picture and the viewing distance. Any departure introduces distortions.

This may seem a limitation, but it actually introduces the opportunity to obtain some very interesting effects. Of course a flat picture has only one proper viewing point for any given size, although one can depart from this quite substantially before the distortions become annoying. Such distortions can be detected in stereoscopy simply by moving the head from side to side and noting the change in shape of the object.

Now the interesting fact is that we do not necessarily want a properly shaped image. Perhaps an exaggerated depth will be more effective, if so we can provide it. Needing to know how to achieve proper shape as a point of departure, we use formulas for determining the proper interocular under any conditions.

Though these formulas are basic, each practitioner uses them to determine what interocular he should use and then departs from this interocular to suit his taste, either aesthetic or theatrical.

The possibilities are infinite, and I have no doubt that publications which approach photography as an art will soon be filled with erudite articles on the aesthetic effect of various interoculars. We shall probably run through the same sort of fashions in stereophotography as we have in flat photography viewed as an art.

At the present moment the uses of stereo in teaching have probably been given the most attention and will probably be of interest to the reader, for they present some very interesting techniques. Furthermore, this is my own field, and therefore the one I most enjoy discussing.

USE OF MODELS AND STEREOSCOPIC DRAWINGS

In addition to straight photographs, a great deal has been done with models and with stereoscopic drawings. The latter have very powerful possibilities. In the former application, the Navy uses vectograph slides of models in teaching celestial navigation. Their value over actual models lies chiefly in the fact that they are quite large, can be produced cheaply in quantity, and can be transported from place to place in very small packages.

Another very fruitful field is that of mathematics. I have yet to find a student who is capable of seeing in three dimensions at all who hasn't had his attention captured by stereoscopic drawings far more than by any other means. Furthermore, the pleasure of three dimensions does not seem to dim with long acquaintance. Before closing we should mention the movies and touch briefly on some of the difficulties of stereoscopy.

USE BY MOTION-PICTURE INDUSTRY

The vectograph should be the answer to the stereoscopic movie. The problems still to be surmounted are chiefly technical ones of registration, film lamination, and the like.

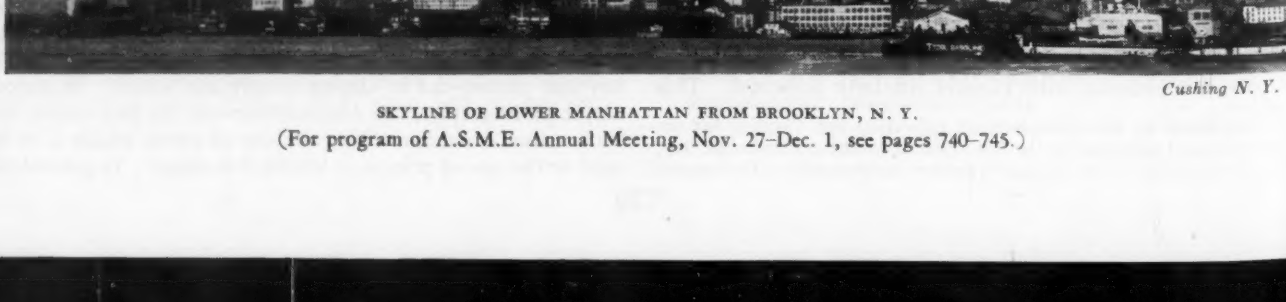
In so far as the industry itself is concerned the only necessary changes are the use of double cameras, the use of aluminized screens, and the problem of persuading the audience to use viewers. Of course many movie techniques will have to be revised. Backdrops and dodges of that sort and existing film libraries will all have to be abandoned. Probably a new set of stars will be necessary since photogenicity in two dimesions doesn't guarantee it in three. The results are frequently quite different.

None of these obstacles is insurmountable. The technical ones are in the process of being liquidated. The viewer problem is simply one of habit. Probably you will own your own viewers or pay five cents extra for admission.

The chief problem of stereoscopy, other than the eternal one of interoculars, is that of eye strain. This is chiefly a problem of care; the elimination of verticals, the avoidance of too great a separation between views, and the like. There is of course inherently a difference between viewing a scene and viewing a stereo in that in stereo the eyes are constantly focused for the distance to the screen while the convergence changes.

Different individuals differ in their ability along these lines, but it is perfectly possible to hold pictures well within the strain point for all but those of the poorest vision. If an individual cannot see the stereo at all, and there are quite a number who cannot, he need only wear spectacles with both polarizers oriented for one picture, and he will simply see a flat movie.

Another interesting phenomenon involves the limits of stereo vision. It would seem that an object 1 ft deep, viewed from 1 ft, would appear to have more depth than one of 6 in. viewed from 6 in. But this is deceptive, for an object 1 mile deep viewed from 1 mile appears to have no depth at all because it is beyond the limits of stereovision. Again, as one moves back from the screen, a three-dimensional scene seems to get deeper, but by continuing to move back the ability to detect depth decreases with increasing rapidity, and though the scene is deeper on optical principles, one is no longer able to detect it. In fact at 100 ft, stereo begins to get feeble. This can be avoided by bringing the image forward from the screen, but the accommodation-convergence problem soon arises when this is done. This problem has not been fully investigated, but it would seem to dictate rather small stereotheaters.



Cushing N. Y.

SKYLINE OF LOWER MANHATTAN FROM BROOKLYN, N. Y.

(For program of A.S.M.E. Annual Meeting, Nov. 27–Dec. 1, see pages 740–745.)

INDUCTION FURNACE *for* MELTING ALUMINUM

By MANUEL TAMA

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THE core-type induction furnace operates on the principle of a short-circuited transformer. Fig. 1 shows the fundamental parts of the electric circuit. Alternating current of power-line frequency is applied to the primary coil A, made of high-conductivity material. The coil surrounds a laminated core B, made of low-loss high-saturation steel. The ring C, surrounding the primary coil, represents the molten metal which is contained in a receptacle of refractory nonconductive material (not shown).

If an alternating electromotive force E_1 is applied to the primary coil having n turns, a primary current I_1 will flow through. At the same time a secondary current of the magnitude $I_1 \cdot n$, will flow through the molten-metal loop C, in the opposite direction. The secondary current is usually very large and creates heat in the secondary circuit, having a resistance R_2, according to Joule's law

$$W_0 = I_1^2 \cdot n^2 \cdot R_2$$

If the heat thus generated is larger than the heat losses of the apparatus, the temperature will rise until equilibrium is attained. There will always be an equilibrium temperature for each particular apparatus. The energy required to hold the molten bath at a constant working temperature (usually called the idling power W_i) can easily be measured in furnaces provided with automatic temperature controllers. It is only necessary to set a certain temperature on the controller and to measure the energy with the wattmeter or the watthour meter. The efficiency of the furnace is given by the equation

$$l = \frac{W_0 - W_i}{W_0}$$

where W_0 is the operating power and W_i the idling power. W_i consists of copper and iron losses in the transformer which are very small and, further, of heat losses through the furnace walls and through the opening of the furnace. The heat losses through the metal walls are determined by the dimensions of the walls and the heat conductivity of the refractory and insulating materials used for their construction. A certain amount of temperature drop must be allowed within the refractory walls, and therefore a certain amount of heat losses must be taken into account.

A large temperature gradient within the refractory prolongs to a large extent the life of the lining, and this again depends upon the nature of the metal to be melted. Metals attack refractories differently—some vigorously, others to a lesser degree. In dealing with metals which are very destructive to the lining, it is often necessary to allow for a larger temperature drop or heat flow through the refractory walls to insure a longer life of the refractory. The heat losses through the charging openings of the furnace increase with the fourth power of the absolute temperature of the metal and depend, further, upon the size of the opening and the emissivity coefficient of the metal bath. For instance, in an aluminum bath, much greater losses are measured when the metal bath is covered with a slag rather than with a clean metal, because the emissivity coefficient of aluminum is very low and increases considerably when a slag cover is used.

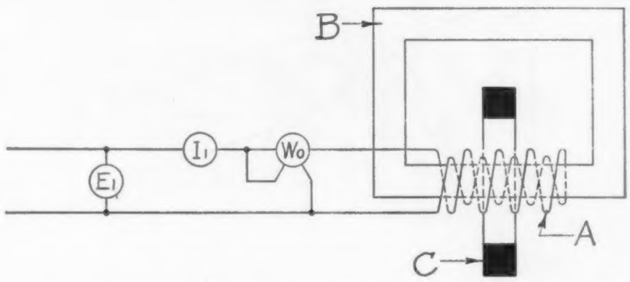


FIG. 1 FUNDAMENTALS OF ELECTRIC CIRCUIT

Measurements made on the primary side of the furnace circuit show that the current is out of phase with the voltage, the lag being determined by the phase angle φ. Voltage, current, power, and phase angle are linked by the following equation

$$W_0 = E_1 \cdot I_1 \cdot \cos\varphi$$

where W_0 is the power in watts, E_1 the primary voltage in volts, I_1 the primary current in amperes, and φ is the phase angle.

If the voltage is varied and measurements are made without otherwise changing the circuit, it is found that the power varies with the square of the voltage, that the current varies proportionately to the voltage, and that the power factor does not change. The induction furnace can therefore be considered as an apparatus with constant impedance.

In electric circuits of this type, the reactance Y can be considered as constant as long as the shape of the secondary circuit is not changed. If metals with different resistivities are charged the resistance will vary.

The maximum of power is obtained from a furnace of given design when the reactance is equal to the resistance, or when the phase angle φ is equal to 45 deg, or when the power factor $\cos\varphi$ is equal to 0.707.

Fig. 2 shows the performance chart of a 60-kw furnace described later. The power, current, and power factor are plotted in this graph for changing specific resistances of the metal charged. The chart shows that the maximum power is obtained for a power factor of 0.707. The reactance of the circuit is given by the geometrical shape of the secondary which determines its coefficient of self-inductance L in henrys and the frequency f, according to the equation

$$Y = 2\pi \cdot f \cdot L$$

Under otherwise equal conditions, the power factor will increase if the frequency is decreased. This fact is mentioned, because, in the early stages of induction-furnace development, it was thought that lower than standard frequencies should be used. This reasoning is not correct because the lower frequencies require larger transformers, both factors tending to counteract the advantages of the lower frequency in regard to improvement of power-factor.

Contributed by the Production Engineering and Metals Engineering Divisions and presented at the Semi-Annual Meeting, Pittsburgh, Pa., June 19–22, 1944, of The American Society of Mechanical Engineers.

SPECIFIC RESISTIVITY OF MOLTEN METALS

The resistance of the circuit is determined by the geometrical shape of the secondary and by the specific resistivity of the molten metal contained in the secondary loop. Fig. 3 shows the values of the specific resistivities of different metals in the molten state. The metals of very low resistivity are silver, copper, aluminum, and gold. The metals of higher resistivity are mercury, lead, and nickel. All the other metals have resistivities lying between these two extreme cases. All the metals show a sudden increase of resistivity at the melting point. Manganese behaves differently. It shows decrease of resistivity at different phase changes, including the transition from the solid to the molten state, according to Grube and Speidel.[1] The resistivity of alloys in the molten state cannot be determined from the resistivity of the component parts. Special measurements have to be made from case to case.

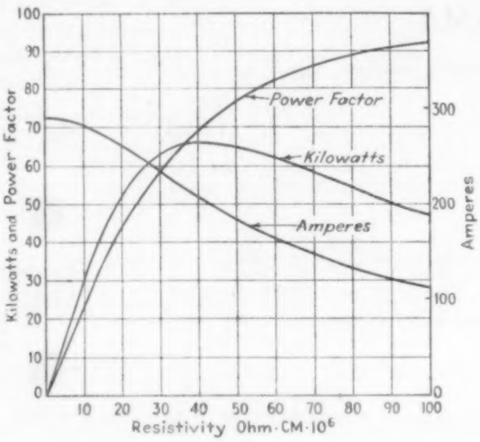


FIG. 2 PERFORMANCE CHART OF 60-KW TWIN-COIL, 60-CYCLE INDUCTION FURNACE

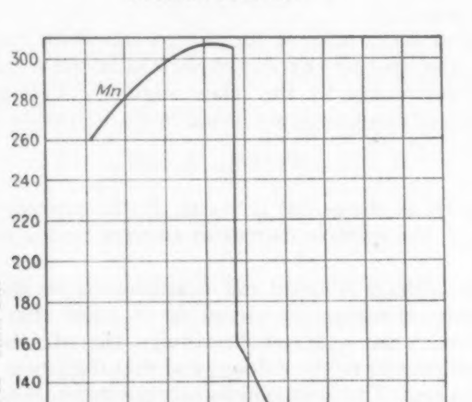


FIG. 3 SPECIFIC RESISTIVITY OF PURE METALS IN SOLID AND MOLTEN STATES

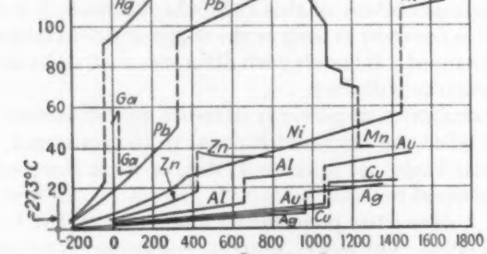


FIG. 4 HEAT CONTENT OF ZINC, ALUMINUM, COPPER, AND IRON EXPRESSED IN TERMS OF ENERGY PER POUND AND PER CUBIC FOOT

HEAT CONTENT OF MOLTEN METALS

The energy required for melting metals, usually called the "heat content," consists of three parts: namely, (1) the heat required to raise the temperature of the solid metal to the melting point; (2) the latent heat necessary to change from the solid to the molten state at the melting temperature; (3) the heat needed to raise the molten metal to the desired pouring temperature. The total amount of heat thus required is usually plotted in charts, like that shown in Fig. 4, which gives in solid lines the heat content of the principal metals (aluminum, copper, iron, and zinc) in terms of kilowatthours per pound at different temperatures. It will be noted that aluminum needs much energy per unit of weight for melting and is only surpassed by iron.

However, inasmuch as many of the physical characteristics of metals, such as tensile strength and electrical conductivity, are not judged by weight, it is also interesting to plot the heat content in terms of kilowatthours per cubic foot; in other words, in terms of energy per unit of volume. Fig. 4 also shows the heat content of the same metals plotted in this manner in dotted lines, and it will be seen that aluminum has a low heat content per unit of volume as compared with the other metals.

HISTORY OF INDUCTION FURNACES

The first induction furnaces were made around 1890. An induction furnace of the open-ring type was built by Kjellin in Sweden in 1891. A description of this furnace and of the Roechling-Rodenhauser furnace (to be described) has been published.[2] It consists of a transformer assembly with primary coil, iron core, and secondary circuit of ring type of uniform cross section over its entire length. The molten metal, which forms the secondary circuit, is contained in a horizontal trough of refractory material. It is obvious that in this type of furnace, the level of the metal contained in the trough varies within a wide range from the beginning to the end of the melt. The trough cannot be emptied completely. A heel of molten metal is maintained therein at all times, and when melting is started, ingots are charged into the trough, thereby increasing the level of the molten heel. Obviously, the resistance and the reactance of the secondary are thereby reduced and the furnace will take less power at the beginning and more power at the end of the melt.

These conditions are by no means ideal because the power absorbed by the furnace during the operation fluctuates too much, thereby affecting seriously the over-all load factor of the furnace. An ideal furnace should draw steady power.

Another disadvantage of the ring-type induction furnace is the low power factor. In fact, the power factor of this furnace was so poor that very low frequencies had to be used for correcting the power factor. How the frequency affects the power factor was previously explained. Frequencies down to 5 cycles per sec were suggested for furnaces of large capacities, and therefore large motor generator sets were used. These furnaces were used at that time chiefly for melting steel.

[1] "Die Elektrodenlose Messung des Elektrischen Widerstandes von Metallen und Legierungen bei Hoher Temperatur," by G. Grube and H. Speidel, *Zeitschrift für Elektrochemie*, vol. 46, 1940, pp. 233–242.

[2] "Electric Furnaces in the Iron and Steel Industry," by W. Rodenhauser, J. Schoenawa, and C. H. von Baur, third edition, John Wiley & Sons, Inc., New York, N. Y., 1920.

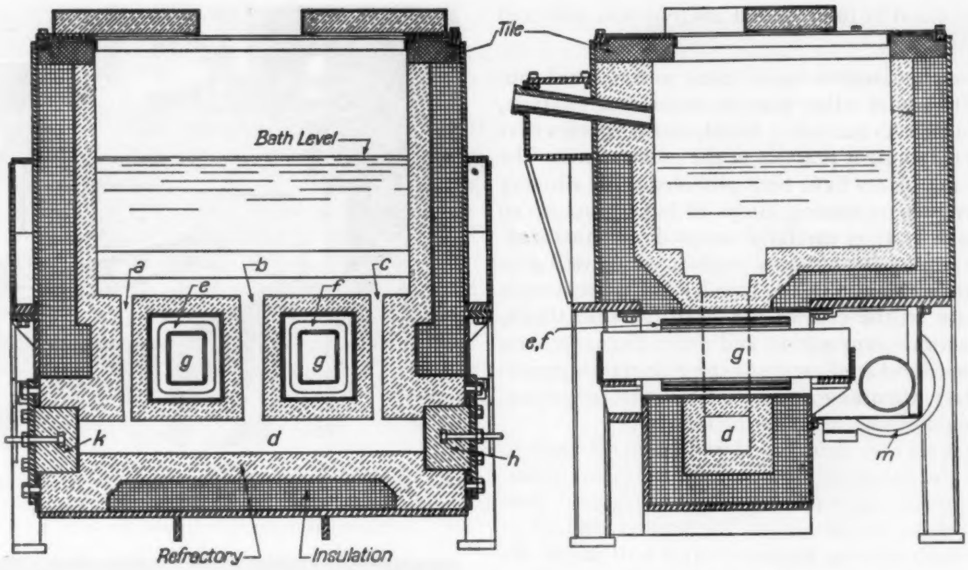


FIG. 5 PRINCIPAL VERTICAL SECTIONS OF INDUCTION FURNACE FOR ALUMINUM

Further improvements were made when the Roechling-Rodenhauser furnace[2] was constructed. This furnace also had a horizontal bath with zones of constricted cross sections connected to a larger hearth. In these furnaces the resistance of the secondary was considerably increased, but still there was a difference of metal level between beginning and end of melt and, consequently, a fluctuation of the power absorbed by the furnace. Several furnaces of this type were built for steel-melting, but none of them has persisted until today.

While in all these furnaces there was a tendency to use lower frequencies, Dr. E. F. Northrup, about 1920, worked on the development of a coreless-type high-frequency furnace. The Ajax-Northrup furnace and the Ajax-Wyatt furnace mentioned later have been described by Stansel.[3] At that time reliable electrostatic capacitors had been made available to the industry, and Dr. Northrup relied on the fact that the power factor of the furnace could be cheaply improved by capacitors if the frequency applied to the furnace was increased. The price of capacitors for a given output decreases when the frequency of the circuit is increased. The high-frequency furnace is now used extensively for melting high-quality steels and other high-temperature metals.

The induction furnace was successfully adapted to the melting of brass by J. R. Wyatt around 1917. In this furnace, which is of the submerged-resistor type, the secondary circuit consists of a loop of molten metal contained in a refractory lining and connected to a large hearth located above the loop. In this case a heel of molten metal is always left in the furnace. The furnace is primed by pouring molten metal into the properly preformed and prefired lining. The molten-metal level fluctuates during the melting only in the hearth, while the loop, or submerged resistor, is always full of metal. The resistance and reactance of the secondary circuit are only very slightly affected by the changing level in the hearth. The furnace therefore draws constant power during the entire melting operation, thus improving considerably the load factor of the melting equipment. This type of furnace is now in world-wide use for melting brass and other copper alloys.

INDUCTION FURNACES FOR MELTING ALUMINUM

It was a long time before the submerged-resistor type of furnace could be adapted for the commercial melting of aluminum and aluminum alloys. The difficulty lay chiefly in the low specific gravity of aluminum alloys. In the heavy metals, the slags, or nonmetallic particles contained in the melt, are much lighter than the metal, so that they tend to float on the surface of the bath. In the light metals the slag particles have about the same specific gravity or are heavier than the melt. Obviously, if nonmetallic nonconductive particles are contained in the secondary loop of an induction furnace, they will tend to increase the resistance of the secondary and to change the characteristics of the furnace.

Furthermore, such slag particles tend to stick to the walls of the melting channels and gradually to decrease their cross section. Therefore, when attempts were made to melt aluminum in the submerged-resistor furnace, designed for brass and other heavy metals, the resistor channels were clogged up by nonmetallic particles which adhered to the channel walls.

Fig. 5 shows an induction furnace of the submerged-resistor type in which aluminum alloys can be melted continuously without fear of clogging the melting channels. The secondary circuit consists of two or more straight vertical channels connected at the bottom by a horizontal channel of larger cross section. Depending upon the kind of metal charged into the furnace, there will be some deposits of slags in the channels chiefly in the vertical legs. However, these deposits can be easily scraped off from time to time by using tubular tools having the same cross section as the channels. The slag particles are scraped off and can in most cases be extractedfrom the surface of the metal.

MELTING OF ALUMINUM IN FOUNDRIES

The most widely used method of melting in aluminum-alloy foundries consists of a combination of melting and holding furnaces. The raw metal, in the form of pigs, scrap, risers, and gates, is charged into large melting furnaces. Molten alloy of the desired composition and temperature is tapped from the melting furnaces and transferred to holding units of smaller capacity and melting rate.

This method has been considered necessary heretofore for the following reasons:

1 The larger fuel-fired melting furnaces are more efficient than the smaller ones. Therefore, the over-all efficiency of the furnace installation was increased by the combination of the two types.

2 The close temperature range needed at the molds was easier to maintain with a small holding furnace of limited capacity.

3 In some cases, where the foundries prefer to prepare their own alloys, the alloying was performed in the large melting

[3] "Industrial Electric Heating," by N. R. Stansel, John Wiley & Sons, Inc., New York, N. Y., 1933.

units, and molten metal of the required analysis was delivered to the melting units.

The trend of the aluminum industry seems to be toward supplying the foundries with alloy pigs of guaranteed analysis, either from virgin or from secondary metal, and it appears that this will be the predominant practice in the postwar era. The aluminum-producing plants have been provided with alloying equipment. They prepare casting alloys in large heats up to 20,000 lb, and each heat is carefully sampled and analyzed. Every precaution is taken to obtain a product which will give uniformly satisfactory results in the foundry. This control is especially necessary in the case of the heat-treatable alloys, because close chemical composition and other characteristics are essential to successful application of the heat-treating process. The secondary aluminum industry takes similar precautions for supplying uniform ingots to the foundries.

Therefore, it appears that there is and will be no necessity to prepare alloys in the foundries, and that the prevalent procedure will consist of starting with ingots of the required composition. Under these circumstances, the logical method of melting should consist of using furnaces which will enable the foundries to use only one furnace for melting and discharging, thus obviating the necessity of double melting and of transferring molten metal from one pot to the other.

A furnace capable of being used in the manner just described should answer to the following requirements:

(*a*) Large melting capacity in small space.
(*b*) Close temperature control, while cold metal is charged and molten metal discharged continuously.
(*c*) Comfortable operating conditions with only small amounts of heat being radiated to the surroundings.
(*d*) Thorough mixing of the molten bath.

The standard frequency induction furnace of the submerged resistor type seems to answer to these requirements.

CONTINUOUS MELTING AND POURING

A large die-casting company once requested the building of an induction furnace in which a solid piece of metal could be inserted and brought to a molten state with high power within a few seconds, so that the molten metal could be charged immediately into the chamber of the die-casting machine. Although such operating conditions would be ideal from every angle, it was thought that it would be too expensive to follow such a procedure. In the first place, the piece of metal to be inserted would have to be of the exact weight as the piece to be cast, the shape would be different from the pigs delivered by the smelters, and the power required to do the job would be very high because of the intermittent character of the operation.

From this idea, however, a new method of operation was developed in conjunction with the induction furnace. This process has now been adopted by several foundries in this country. It is proposed to build small units with high power capable of melting at a high production rate and of being charged and discharged continuously with the standard pigs available to foundry use. For example, a furnace of 60 kw capacity delivers molten metal at a maximum rate of 300 lb per hr. The pigs are charged continuously into the furnace, and molten metal is ladled out from the same furnace, keeping pace with the production of the die-casting machines or permanent molds.

In operations of this kind, it is very important to maintain a uniform temperature of the melt during the entire production cycle. The furnace will melt all the solid metal charged into it at a certain rate corresponding to the kilowatts absorbed. If too much cold metal is charged, the temperature of the bath will drop. If the cold metal is charged too slowly, the temperature will increase. It was therefore necessary to develop methods and devices for handling pigs of large size and yet maintain a uniform temperature of the bath at the point from

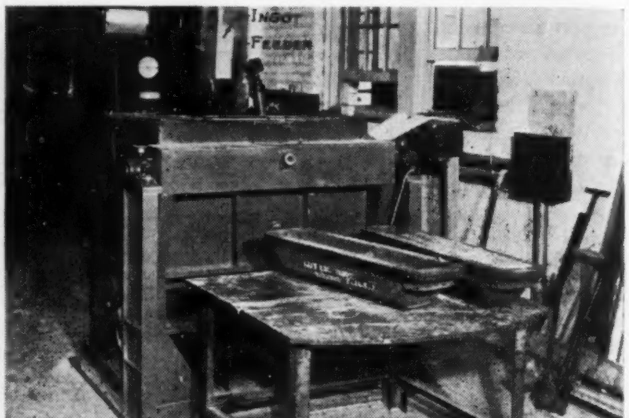


FIG. 6 FURNACE OF 60 KW CAPACITY WITH FEEDER DEVICE TO CONTROL MELTING SPEED

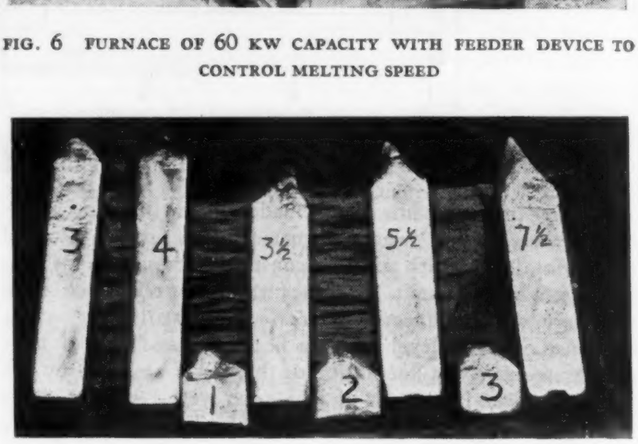


FIG. 7 INGOTS REMOVED FROM FURNACE BEFORE REACHING THE COMPLETELY MOLTEN STATE

which the molten metal is discharged. The size of the standard pigs has been considerably increased, and the trend of the aluminum-producing industry is to deliver alloy pigs of 50 to 60 lb.

Fig. 6 shows a furnace of 60 kw capacity provided with a feeder device to control the speed of melting. The depth of immersion is controlled by a piece of refractory material placed under the feeder. If this precaution is taken, the pig will gradually melt and sink into the bath at a quite uniform speed. If the metal is ladled out continuously at the same rate of production, the metal level will be maintained during the entire operation, and the temperature of the bath is then uniform. This speed of melting is regulated by the depth of immersion, the power of the furnace, the metal contents of the bath, the shape of the pig, and the composition of the alloy. The furnaces are, of course, provided with automatic temperature controllers which will reduce the power as soon as the desired temperature is reached and switch over to full power as soon as the desired minimum temperature is attained.

Fig. 7 shows ingots which were removed from the furnace before they were completely molten. These experiments were made at different depths of immersion which are marked on each ingot in inches. It will be seen from these views that the pigs have a conical shape at the immersed end, which is in accordance with the laws of heat transfer. In operations of this kind, it is practical and possible to hold the temperature of the bath within 10 to 15 deg F, which seems adequate for this type of operation. This appears to be a simple way of combining melting and holding units to one piece of equipment without too many complications. It will only be necessary to charge the pigs on a certain schedule. Of course it is always possible to place the next pig on the feeder before the previous one has been completely melted and to discharge the metal also on a

certain schedule. This latter requirement is not difficult, because the amount of molten metal required by the die-casting machines or permanent molds is usually uniform and on schedule.

This method of course can only be used for charging ingots of uniform composition. Here again the trend of the primary and secondary smelters in this country is to produce alloy ingots of guaranteed analysis; and this method of operation therefore fits very well with the present and future requirements of the industry.

Gates and risers or other solid scrap of the same composition can also be handled in this manner. They are smaller in size and weight than the smelters' ingots and are easier to handle. This method would not apply to the remelting of turnings for which it is recommended that a special induction furnace for melting and pigging be used.

ROLLING MILLS

Fig. 8 shows a part of a battery of twenty-four furnaces operated by a prominent mill in one of the Allied countries. The layout is similar to that used for many years in the brass mills. All the furnaces are placed in a row mounted on a charging platform. The charges are brought to this platform by trucks or monorails. The electrical control equipment is near the furnaces. The furnaces are provided with individual tilting devices which allow pouring the molten metal when a charge is ready. In this particular case, the molten metal is discharged into large ladles and brought to the molds. It is of course feasible and practical to place individual molds in front of the pouring spout of the furnace and to discharge directly from the furnace into the molds, exactly the same way as all the brass mills operate today.

MELTING IN SAND-CASTING FOUNDRIES

The requirements of sand-casting foundries are different from the die-casting and permanent-mold plants. Larger amounts of metal have to be taken from the furnaces and no special precautions are necessary for maintaining a certain temperature during the melting period other than to prevent an unnecessary rise of temperature. This, of course, can always be achieved by the temperature controller. The sand-casting furnace is provided with a tilting equipment which allows discharge of the metal around the pouring spout. The time of melting and schedule for discharging can be adapted to suit the requirements of the casting shop. Metal can be taken from the furnace at any time as soon as the desired amount is ready for casting, so that the metal can be discharged by smaller ladles or by pouring directly into sand molds.

GAS ABSORPTION

The gas pickup of aluminum alloys is one of the most difficult problems the aluminum melter has to confront. A vast amount of research has been carried on in this field in the United States and abroad. The British have been especially successful in this work, and the *Journal of the Institute of Metals* in London contains a number of excellent papers on the subject.

All investigators agree on certain principles which have crystallized into the following fundamentals:

1 Most harmful is hydrogen and hydrogen dissociated from moisture contained in the atmosphere surrounding the bath.

2 All the other gases are less harmful.

3 Gas pickup increases considerably when the temperature is raised.

The induction furnace is not the cure-all for avoiding gas pickup. However, users of induction furnaces have not reported any failures due to gas pickup in the melting stage, up to the present time. Hydrogen, of course, is not present in the gases covering the molten bath contained in an induction furnace. Moisture may be contained therein or may be brought in with the cold charges, especially on humid days. However, the temperature existing above the metal bath is low. The induction furnace is decidedly a cold-top furnace. The highest temperature is found at the bottom of the furnace. Slightly lower temperatures are observed on the surface of the bath, and considerably lower temperatures are measured on top of it.

Most of the users of induction furnaces for foundries report that they are using no fluxes. One large rolling mill, casting large billets for extrusion and forgings, reports that over a long period of time they have found only one half of the degassing agents to be necessary as compared with other furnaces. Further experience will have to reveal whether or not the induction furnace can be used as it is for standard melting without fear of gas pickup. It may be mentioned that the induction furnace has been the key to the development of commercial large-scale methods of producing oxygen-free and gas-free copper. The

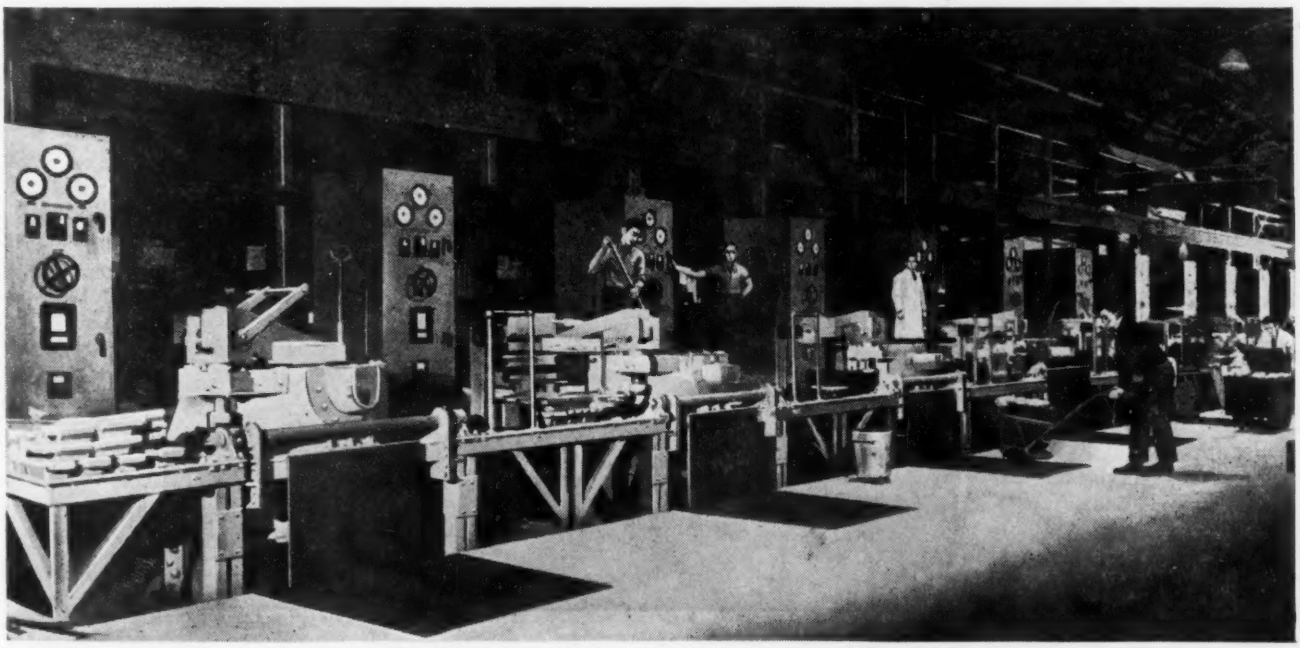


FIG. 8 PART OF BATTERY OF TWENTY-FOUR FURNACES OPERATED BY A PROMINENT ALUMINUM-ALLOY ROLLING MILL

induction furnace, with its characteristic features of internal production of heat and of a totally enclosed metallic shell, offers unlimited possibilities to the use of controlled atmospheres under high and low pressures for melting of metals.

HARD SPOTS

Another source of trouble in aluminum melting is the occurrence of hard spots due to nonmetallic particles contained in the molten metal discharged from the furnace. These inclusions are harmful particularly in cases where the castings are subjected to machining operations. In this connection, induction furnaces of the submerged-resistor type are characterized by a more or less violent and constant movement of the metal content in the hearth during the melting operation. At the beginning of our research and development work on induction furnaces, the objection was often raised that this movement would be harmful to the melting of aluminum. In the conventional method of melting, it was found that the quiet bath was desirable. One of the chief objections was that the movement of the bath would prevent the nonmetallic particles from settling at the bottom of the crucible and that hard spots would be inevitable. However, experience has shown that the movement of the bath is in no way harmful to the quality of the product. On the contrary, at least four users of induction furnaces, who have to do a considerable amount of machining on the castings, have reported that they have found no evidence of hard spots caused by the stirring action of the furnace. It appears that nonmetallic particles contained in the bath are highly attracted to the melting channels from which they can be liberated from time to time, or that they are expelled to the surface where they tend to adhere to the oxide layer which is inevitably formed on the top of the molten aluminum.

PRODUCTION OF HARDENERS OR MASTER ALLOYS

By reason of the same violent movement of the bath, the induction furnace offers the best possibilities for preparing alloys of aluminum with ingredients of higher melting point or of poor solubility in aluminum. These conditions, of course, are very easy to explain in exactly the same manner that sugar is more easily and quickly dissolved in moving water than in quiet water. We have found that it is possible to dissolve with certainty all kinds of metals in molten aluminum in the amount and at the rates and temperatures indicated by the constitution diagram. Copper, silicon, nickel, magnesium, iron, titanium, chromium, and many other metals have been successfully and quickly dissolved in aluminum melts contained in the hearth of an induction furnace.

The solution is almost instantaneous. When a certain amount of solid ingredients, i.e., metals like iron or nickel, are immersed into the bath and brought to the temperature required for solution according to the constitution diagram, the time required for dissolving these ingredients is almost equal to the time required for transmuting the ingredients from the solid state to the molten state. Furthermore, by virtue of the same movement of the bath, the solution is uniform as shown by careful tests of each individual ingot obtained from a batch treated in this manner.

Metlbond—A Metal Adhesive for Aircraft

(*Continued from page 714*)

In conclusion, we can state that Metlbond represents a forward step in the bonding of materials. The development of Metlbond is not static; rather, new types and combinations of existing Metlbonds are being tried constantly. Metlbond has been approved by the Army for many parts; it is being used in production in plants of the author's company, and an expansion of its use will take place as soon as necessary facilities can be obtained. Up to the present time, it has not been released to outside concerns. Those desiring to use the material should address the office of the Director of Engineering of Consolidated Vultee Aircraft Corporation.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the encouragement given by Colonel P. H. Kem mer and Captain D. L. Grimes of the Army Aircraft Laboratories who have fostered Metlbond as well as other such developments. The development was made under the direction of H. A. Sutton, A. P. Fontaine, T. P. Hall, and Bruce Smith. The Metlbond group who, through their efforts, have made the development possible received considerable aid in the selection of materials from the Bakelite Corporation and E. I. du Pont de Nemours Company.

Cushing, N. Y.

AT THE EARLY MORNING MARKET IN NEW YORK CITY

(For program of 1944 A.S.M.E. Annual Meeting, Nov. 27–Dec. 1, see pages 740–745.)

COMMENTS ON PAPERS

Including Letters From Readers on Miscellaneous Subjects

Coal Segregation

Comment by H. C. Huston[1]

The writer is in general agreement with the conclusions reached in this paper,[2] i.e., that coal reaching a furnace in a segregated state, especially when burned on a grate, has a detrimental effect on the over-all performance of the unit.

Of course, there are numerous cases of what would appear to be a condition brought about by segregation of coal which may be due to other factors. Often a close check is necessary to determine just where the fault lies, before the proper corrective measures can be taken.

The installation of a nonsegregation chute does not always insure good distribution because the chute is dependent to no small extent on the manner in which the coal is delivered to it. Therefore, it would seem that those engineers and designers having to do with the design, manufacture, and installation of coal-handling and storage equipment, from the track hopper to the service bunker and then to the stoker, must, in order to secure the desired over-all result, pay particular attention, not only to the design of the various component parts, but also to their relation one to another, when installed.

Bunker or silo segregation is most undesirable, regardless of the means employed to transfer the coal from the bunker or silo to the furnace, whether it be a fixed chute, lorry, or swinging spout. Unstable fuel beds often result even with the most carefully operated transfer means, due to bunker segregation. Fires broken across the entire grate width as a result of this condition have been observed. Constant local variations over the active burning area quite often result from just this condition. No chute spout or lorry will always entirely correct this condition.

Reducing the air pressure under the low-resistant areas, and increasing it under those areas having a higher resistance to air flow, can, of course, be done. This may be accomplished by automatic means, differential controls, etc. However, when considering the equipment involved, its cost, and the operating and maintenance difficulties, the average coal-burning plant would probably find it hard to justify its installation. If such regulation is manual, then the operation more often than not does not see the need for regulations until after the damage has been done. Therefore, it is believed that the entire coal-handling system must be taken into account and treated as a part of the steam-generating unit. It may well be that the need for more complicated control and regulation devices could be reduced and in many cases eliminated.

Referring to the condition of unequal air flow to the stoker grate; some types of stokers, due to their design, operate with a relatively thin fuel bed, providing means for even air flow, finely divided through the grate. With these low-resistant grates and fuel beds, considerable care must be exercised not only in the design selection, but also in the correlation of fans, ducts, and controls. If air velocities and total pressure are low and this condition localized, then a furnace condition not unlike that caused by coal segregation will be observed, and with similar effect on the over-all performance. Improperly tempered coal will alsoresult in uneven burning, causing much the same effect as segregated coal.

[1] Johnston & Jennings Company, Cleveland, Ohio.

[2] "Coal Segregation in Boiler Plants," by A. J. Stock, Mechanical Engineering, vol. 66, 1944, pp. 523–528.

Comment by H. C. Linderman[3]

The author has covered simply and well the important phases of the problem of coal segregation throughout the plant coal-handling system. It is of real consequence that this point receive thorough and effective consideration in the design of the entire coal-handling layout, from yard to furnace.

The nonsegregating coal spreader of various designs indicated by the author has won wide acceptance. It is usually included in the design of new installations today. The design of the bunker, or other storage element, and the means for filling and emptying it seems to have been worked out, however, without consideration of the segregation problem. As a result, the operating difficulties indicated by the author occur all too frequently.

Beyond the fact that changes in the size of the coal received by the combustion equipment result in combustion or pulverizing difficulties, there are other objectionable consequences.

Since changes in the size of the coal result in changes in the heat content per unit of volume of fuel, and since the fuel is fed by volume, the combustion-control apparatus must be readjusted for each considerable change in the size of fuel if best combustion performance is to be maintained. This factor alone has considerable adverse effect on the stability of operation.

Further, in the case of all stokers, the stoker adjustments must be changed to suit the size of the coal. This also reduces the stability of operation.

There exist many installations in which segregation of the coal in the bunker could be minimized, if not prevented, by proper manipulation of the conveyer to the bunker. It seems all but impossible however, to enforce instructions regarding such manipulation.

It is hoped that greater efforts will be expended designing coal-handling apparatus to eliminate segregation by basic design rather than by manual control.

[3] Central Stoker Supervisor, Westinghouse Electric & Manufacturing Company, Pittsburgh, Pa. Mem. A.S.M.E.

Comment by J. S. Bennett[4]

The writer has followed the author's work in coal-handling for many years with a great deal of interest. He has made a real contribution to the art of coal burning and has made coal users increasingly conscious of the harmful effects of uneven distribution of coarse and fine coal particles.

There is another aspect of coal supply which has not been treated at any length in this paper, undoubtedly intentionally, because of the fact that this subject, interruption of coal feed, would require more space than is available to cover it adequately. Our experience in burning coal on the multiple-retort underfeed stoker has taught us that good performance is impossible without uniform distribution of coarse and fine coal across the width of the furnace, and without a continuous, steady movement of coal over the stoker fuel bed. The best distribution system will fail if the stoker itself causes coal bridging and uneven feed. This problem has been faced for over a quarter of a century.

The author has referred to cleanliness in the boiler room. To permit poking in

[4] Vice-President, American Engineering Company, Philadelphia 25, Pa. Mem. A.S.M.E.

the hopper, it was formerly the practice to leave a gap between the coal spreader and the stoker hopper when wet coal was being burned. With the proper agitator this gap may be closed up and the spreader and the stoker hopper sealed to prevent a discharge of dust into the boiler room.

COMMENT BY JOHN VAN BRUNT[5]

The matter of segregation of coal is an ever-present difficulty in the application of traveling-grate stokers, and to a lesser extent in the case of multiple-retort and single-retort stokers.

The author should mention one of the difficulties on traveling-grate stokers caused by segregation, namely, the effect on ignition. Wherever coarse coal segregates on the grate, ignition is slow, particularly with the high-moisture low-grade Midwestern fuels.

[5] Vice-President Engineering, Combustion Engineering Company, Inc., New York 16, N. Y. Mem. A.S.M.E.

The reason, of course, is that the surface exposed per unit of weight is small and the open fuel bed with an excess of lumps permits the flow of an excessive amount of air which prevents the individual lumps from reaching ignition temperature for quite a long period. Therefore, the air must be shut off at the front end of the grate until the retarded ignition takes place. In the meantime, the fines tend to cake and become more resistant to the passage of air, with the result that maybe 20 per cent of the effective grate surface has been lost before the ignition is well established.

The seriousness of the trouble, of course, depends on the extent of the segregation. This difficulty is quite evident with low-volatile fuels such as coke breeze and anthracite coal. With coke breeze the effect on ignition is marked, and where ignition is retarded it is usually difficult if not impossible to burn the fuel completely.

High-Speed Milling

COMMENT BY F. W. LUCHT[6]

It has been a known fact that the amount of the radial rake angle on face-milling cutters has had a direct bearing on the power consumed, the cutter life, and the cutting pressure on the fixture which supports the workpiece.

The present papers[7] report comprehensively a thorough investigation of what happens when the radial rake angles in face-milling cutters are varied through a wide range of positive and negative angles. The authors are to be complimented for the work they have done.

The following points might be raised:

When testing with the calorimetric apparatus, a 0.125-in-deep cut was taken across the end of a 1-in-diam steel bar. This meant that every time a tooth, from the 2-in-diam two-tooth face mill, contacted the workpiece the cutting action was different. This point has been raised because it has been observed that the manner in which the cutting edge of a carbide-tipped face mill first touches the workpiece has a direct bearing on the cutter life. Was any thought given to using a 1-in-square steel bar instead of a 1-in-diam steel bar to give more constant cutting angles with the workpiece at the point of tooth entry at all times? This might tend to produce better all round cutting conditions and more uniform results.

The 2-in-diam two-tooth face mill which was used when testing with the calorimetric apparatus would have to be ground on a tool and cutter grinder in order to hold the runout of the two teeth to a minimum on both the face and the periphery of the cutter. We have found that this cutter-runout problem creates just one more variable factor. This factor has been eliminated in our experimental work by using a flycutter (single-point tool), because there is always less danger of ruining a carbide-tipped single-point tool when it is ground freehand than a multitooth cutter which has to be ground by the fixed grinding method as on a tool and cutter grinder. For this reason we believe that the use of a single-point tool (flycutter) might tend toward more uniform results. Was this considered?

The outstanding results which the authors obtained from the use of the double radial rake angles on face-milling cutters are of real interest. The negative primary radial rake portion of the double radial rake protects the cutting edge and imparts strength to it, while the positive secondary radial rake portion reduces the amount of contact the chip has with the face of the cutting tooth because the chip tends to ride the crest or the intersection of the two radial rake angles. This particular type of grind on the face of the tooth reduces all tendency for the chips to pack into and stick in the fillet at the root of the tooth. In other words, this type of grind, which reduces the chip contact with the cutter, should generate minimum heat and tend toward a cooler milling operation.

The cooler chips will reduce the tendency for them to stick to the face of the teeth and ruin the cutting edge as they hit the workpiece the second time. This will also reduce the heat flow to the workpiece and the tendency to distort it.

It is our intention to study this type of grind in order to determine its merit, because it actually promotes good practice when sharpening face-milling cutters. This is mentioned because we have found that if we grind the face of the teeth on any carbide-tipped face mill which is used to mill steel, the number of workpieces per grind is usually at its maximum. This idea will force grinding to be done on the negative primary radial rake even though many individuals have erroneously considered it not worth the added grinding time.

This method of grinding removes the cratered face of the teeth and the irregularities, which result from it, along the cutting edge so that a smooth and firm carbide cutting edge is again presented to the work. This system of grinding also reduces the wear on the diamond wheel, which is used in the grinding operation, because the corner of the wheel always cuts into the open past the positive secondary radial rake surface. The tendency of any grinding checks developing in the carbide tips is reduced, and the positive secondary radial rake surface may not have to be reground every time the cutter is sharpened.

[6] Development Engineer, Carboloy Company, Inc., Detroit, Mich. Mem. A.S.M.E.

[7] "Determining Tool Forces in High-Speed Milling by Thermoanalysis," by A. O. Schmidt, MECHANICAL ENGINEERING, vol. 66, 1944, pp. 439–442; also "An Investigation of Radial Rake Angles in Face Milling," by J. B. Armitage and A. O. Schmidt, presented as a companion paper at the Semi-Annual Meeting of the A.S.M.E., Pittsburgh, Pa., and appears in Trans. A.S.M.E., vol. 66, 1944, pp. 633–643.

AUTHORS' CLOSURE

The discussion by Mr. Lucht is very much appreciated and the questions raised by him have been investigated experimentally. There is no difference in the results whether a square or round test bar is used in the tests. Since the number of calorimeter tests with each individual cutter was small, no effect was noticed because of the changing entrance of the cutter into the workpiece. Because this would greatly influence tool life, the tool-life tests were made on rectangular test bars while round test bars in the calorimeter were used only for three test cuts at the beginning and end of the tool-life run.

Care was taken to have the cutter ground and checked accurately. At first this caused some inconvenience but could be done more quickly after the tool grinder and inspector had begun to understand the problem involved. We have also used and still use a flycutter because of the reasons Mr. Lucht mentioned, however, a two-lip cutter gives a more balanced cutting action and permits testing two tips at the same time. A two-lip cutter requires more care in grinding but in many cases we have found that it was worth while, and the

results were as uniform as those obtained with a flycutter. J. B. ARMITAGE.[8]
A. O. SCHMIDT.[9]

COMMENT BY O. W. BOSTON[10]

Much of the information given in this paper[11] is for turning with single-point tools. The author has shown "cutter load" (cutting forces in pounds as a total load) and the "shear" expressed in pounds per square inch when turning 17S-T with a single-point tool. The shank in which the tool bit is clamped is of the goose-neck type and carries a small electrical-type strain gage. Various readings caused by the distortion of cutting are obtained on an electrical galvanometer.

The writer has been greatly interested in the application of these small wire strain gages of the electrical type for some time, but through lack of opportunity has not employed them as yet. It appears that the particular toolholder selected for this work is not well adapted to the purpose, inasmuch as the strain gage will record the deflection of the tool, both because of the tangential turning component and its radial component. The writer has determined and published a great deal of information regarding the value of these components as a function of tool shape, cutting speed, and size of cut for various metals.[12]

While no attempt is now being made to check the writer's own results with those given by the author, the general appearance of the curves is similar, and yet it is clear that the latter results do involve both tangential and radial components. The value of the radial component may be equal to or vary considerably from that of the tangential component of the cutting force as the tool shape is changed. Small differences in tool angles cause large differences in the radial force. Therefore, from a practical and scientific point of view, the results given are liable to lead to confusion, since they cannot be used to anticipate results for other conditions.

It is noteworthy to observe that these strain gages can be used successfully in this type of work, and it will be interesting to see the results obtained by the intermittent type of cutting, such as produced by a milling cutter.

REFERENCES

1 "A Research in the Elements of Metal Cutting," by O. W. Boston, Trans. A.S.M.E., vol. 48, 1926, pp. 749–848.

2 "An Investigation of Methods to Determine the Machinability of Malleable-Iron Castings," by O. W. Boston, Symposium on Malleable-Iron Castings, Proceedings A.S.T.M., vol. 31, 1931, part 2, pp. 388–421.

3 "Machining Properties of Some Cold-Drawn Steels," by O. W. Boston, Trans. A.S.M.E., vol. 53, 1931, paper MSP-53-6.

4 "A Simple Cutting Tool for Measuring Pressures in the Direction of Cut," by O. W. Boston and C. E. Kraus, Trans. A.S.S.T., vol. 21, 1933, p. 625.

5 "A Study in the Turning of Steel Employing a New Type 3-Component Dynamometer," by O. W. Boston and C. E. Kraus, Trans. A.S.M.E., vol. 58, 1936, pp. 47–53.

[8] Vice-President in Charge of Engineering, Kearney & Trecker Corporation, Milwaukee, Wis. Mem. A.S.M.E.

[9] Research Engineer in Charge of Metal Cutting Research, Kearney & Trecker Corp.

[10] Chairman, Department of Metal Processing, University of Michigan, Ann Arbor, Mich. Mem. A.S.M.E.

[11] "Determining Tool Efficiency in High-Speed Milling," by W. E. Brainard, MECHANICAL ENGINEERING, vol. 66, 1944, pp. 301–302.

[12] See references at end of this discussion.

AUTHOR'S CLOSURE

This paper was printed in the form in which it was presented at the 1943 Annual Meeting of the A.S.M.E. As all authors were asked to confine their presentations to a specified period of time, detailed description of experimental methods used by the author was omitted.

The tool-bit shank design and the location of the electrical-type strain gage were so chosen that radial and longitudinal loads produced negligible galvanometer deflections. Experimental setups in which variable loads in all three planes, using calibrated tension rings, were used to develop the design. Hence it is believed the results given are acceptably free from radial components. As neither radial nor longitudinal components materially affect the total lathe horsepower requirements, their measurements were intentionally omitted in this particular experiment.

Other toolholders were developed having separate areas of high deflection in all three planes, each equipped with an individual strain gage and recording circuit allowing simultaneous measurement of the three stress components. As the initial results thus obtained were parallel to those of investigators, there seemed no reason to further duplicate their work.

The primary endeavor was to develop a simple and reasonably accurate means of evaluating the tool loads of milling cutters. The methods that had come to the writer's attention, including those referenced by Professor Boston, were not suitable for the recording of instantaneous values of the constantly varying loads occuring during intermittent cutting by milling.

The later portion of the paper described the method of attack using the electrical-resistor-type strain gage. Preliminary results indicated the arrangement was easy to use and that results were consistent. Subsequent to the publishing of the paper, however, the project was shelved for the duration due to the urgency of other research programs.
W. E. BRAINARD.[13]

[13] Tool Planning Supervisor, Consolidated Vultee Aircraft Corporation, Vultee Field Division, Los Angeles, Calif.

Viscosity-Temperature Coefficient

TO THE EDITOR:

I wish to propose a viscosity-temperature coefficient (VTC), defined as

$$VTC = 1 - \frac{\eta_{210}}{\eta_{100}}$$

as a logical means of comparing the viscosity-temperature mutations among a series of oils. η_{100} and η_{210} are the kinematic viscosities in centistokes at 100 and 210 F, respectively.

In comparing high viscosity index oils, such as are being used in aircraft hydraulics, with each other, I have found the viscosity index to be misleading, for it depends as much upon viscosity as upon the rate of viscosity temperature change. This is readily demonstrated by considering the viscosity indexes of a series of "perfect" oils which exhibit no change in viscosity with temperature:

Kinematic viscosity Centistokes (100 F)	Viscosity index
5	300
10	208
20	176
50	149
75	141

Recently the A.S.T.M. slope has come into favor as a substitute for viscosity index. This is the slope of the viscosity-temperature curve when plotted on A.S.T.M. D341 Chart C paper. Since this chart is a log-log viscosity vs. log temperature plot, the A.S.T.M. slope likewise decreases with increase in viscosity grade for a given type of oil.

The advantage of the VTC in comparing hydraulic oils is demonstrated by the following comparison of the constants on two specification hydraulic oils:

Oil	Viscosity at 100 F, Centistokes	Viscosity at 210 F, Centistokes	Viscosity index	A.S.T.M. slope	VTC
AN-VVO-366B	14.7	5.05	226	0.50	0.656
OS-2943	27	10	185	0.375	0.630

The viscosity index indicates that the AN-VVO-366B oil has much better viscosity-temperature properties than the OS-2943 oil. The ASTM slope indicates that the OS-2943 oil is much better. The VTC indicates the true situation, which is that these oils are very nearly alike in rate of change of viscosity with temperature, with OS-2943 oil slightly better than the AN-VVO-366B oil.

DONALD F. WILCOCK.[14]

[14] Research Laboratory, General Electric Co., Schenectady, N. Y.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Program of A.S.M.E. Sixty-Fifth Annual Meeting

New York, N. Y., November 27–December 1, 1944

Headquarters, Hotel Pennsylvania

SUNDAY, NOVEMBER 26

9:30 a.m.

Meeting of Executive Committee of Council

Conference Local Sections Delegates

12:30 p.m.

Luncheon Council and Local Sections Delegates

2:30 p.m.

Meeting of Council

Meeting Local Sections Delegates

7:00 p.m.

Meeting of Council With Professional Divisions, Sections Delegates, and Committee Representatives

MONDAY, NOVEMBER 27

9:30 a.m.

Meeting of Council

Meeting of Local Sections Delegates

12:30 p.m.

Ingenuity Luncheon—Education and Training—Management

2:30 p.m.

Education and Training—Management (I)

Speakers:

Carroll L. Wilson

Dean A. A. Potter

E. H. Armstrong

Meeting of Council

Conference of Local Sections Delegates

4:00 p.m.

Business Meeting

8:00 p.m.

Management (II)

The Returning Service Man

The Selective Service Act and Its Relation to the Returning Service Man, by Brigadier General William C. Rose, War Manpower Commission, Washington, D. C.

* To be preprinted for 1944 Annual Meeting.

MONDAY (*continued*)

8:00 p.m.

Problems of the Returning Service Man From the Viewpoint of Organized Labor, by Clinton S. Golden, assistant to the president, Congress for Industrial Organization, Pittsburgh, Pa.

Aviation (I)—Helicopters

Helicopter Development, by Donnell W. Dutton, director, Daniel Guggenheim School of Aeronautics, Georgia School of Technology, Atlanta, Ga.

Bell Aircraft Corporation Helicopters, by Bartram Kelley, assistant to director, Bell Aircraft Corporation, Buffalo, N. Y.

Rota Wings Helicopters, by Joseph S. Pecker, Rota Wing Corporation, New York, N. Y.

Sikorsky Helicopters

Production Engineering (I)

An Analysis of the Milling Process, Part II—Down Milling, by M. E. Martellotti, research engineer, The Cincinnati Milling Machine Co., Cincinnati, Ohio

Further Researches in High Speed Milling, by Hans Ernst, research director, The Cincinnati Milling Machine Co., Cincinnati, Ohio

Power (I)—Fuels

Discussion of Photographic Analysis of Furnace Performance by several companies

Locomotive Firebox Photographic Analysis, by Walter Leaf, Denver & Rio Grande Western Railroad Co., Denver, Colo.*

Lubrication

Rotating-Load Bearings, by A. F. Underwood, research laboratories, General Motors Corporation, Detroit, Mich.*

Lubrication Characteristics of Involute Spur Gears, by Ernest K. Gatcombe, staff member, division of industrial co-operation, Massachusetts Institute of Technology, Cambridge, Mass.*

MONDAY (*continued*)

8:00 p.m.

Some Thermal Effects in Oil Ring Journal Bearings, by R. A. Baudry, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.*

TUESDAY, NOVEMBER 28

9:30 a.m.

Management (III)

New Horizons for the Engineer in American Industry

Trends in Economic Development, by Ralph E. Flanders, past-president A.S.M.E. and president, Federal Reserve Bank of Boston, Boston, Mass.

Program for Industry, by Scott Fletcher, Committee on Economic Development, New York, N. Y.

Industrial Instruments and Regulators (I)—Fluid Meters

The Coefficients of Herschel Type Cast-Iron Venturi Meters, by W. S. Pardoe, department of civil engineering, University of Pennsylvania, Philadelphia, Pa.*

Piping Arrangements for Acceptable Meter Accuracy, by R. E. Sprenkle, Bailey Meter Company, Cleveland, Ohio*

Remarks on On-Off Control in Resistor-Type Furnaces, by Victor Paschkis, research associate, department of mechanical engineering, Columbia University, New York, N. Y.

Metals Engineering (I)

Some Engineering Properties of Nickel and High-Alloy Nickels, by B. B. Betty and W. A. Midge, International Nickel Co., New York, N. Y.

New Application of Magnesium From the Design and Service Standpoint, by J. C. Mathes, development engineer, The Dow Chemical Company, Midland, Mich.

(*Program continued on following page*)

TUESDAY (*continued*)

9:30 a.m.

Applied Mechanics (I)

The Axial Vibration of Turbine Disks, by Arthur M. G. Moody, De Laval Steam Turbine Co., Trenton, N. J.*

A General Method for Calculating the Critical Speeds of Flexible Rotors, by M. A. Prohl, turbine-engineering division, General Electric Co., West Lynn, Mass.*

Network and Differential Analyzer Solution of Torsional Oscillation Problems Involving Nonlinear Springs, by C. Concordia, analytical division, central station engineering division, General Electric Co., Schenectady, N. Y.*

A New Device for the Solution of Transient-Vibration Problems by the Method of Electrical-Mechanical Analogy, by H. E. Criner, C. D. McCann, and C. E. Warren, Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.

Hydraulics (I)

Prediction of Centrifugal-Pump Performance, by R. J. S. Pigott, chief engineer, Gulf Research & Development Company, Pittsburgh, Pa.

A Study of the Theory of Axial-Flow Pumps, by George Wislicenus, research engineer, Worthington Pump & Machinery Corp., Harrison, N. J.

Fuels (I)

Ignition Through Fuel Beds of Traveling or Chain-Grate Stokers, by E. P. Carman and W. T. Reid, U. S. Bureau of Mines, Pittsburgh, Pa.

Handling and Burning Fuels on Board American Ships, by David Schoenfeld, Combustion Engineering Company, Inc., New York, N. Y., and G. P. Haynes, Todd Ship Yards Corporation

12:30 p.m.

Management Division Luncheon
Wood Industries Division Luncheon
Fuels Division Luncheon
Industrial Instruments and Regulators Division Luncheon

2:30 p.m.

Fuels (II)

Symposium on Future Trends of Fuel

Wood Industries

Preplanning of Logging Operations for Minimum Costs, by Prof. Don M. Matthews, University of Michigan, Ann Arbor, Michigan, and John A. Willard, Bigelow, Kemp & Willard, Boston

Modern Uses of Coated Abrasives in the Woodworking Industry, by Thomas Trowbridge, Behr-Manning Corporation, Troy, N. Y.

TUESDAY (*continued*)

2:30 p.m.

Laminating Lumber for Extreme Service Conditions, by C. D. Dosker, Gamble Bros., Inc., Louisville, Ky., and A. C. Knauss, Forest Products Laboratories, Madison, Wis.

Management (IV)

The American Engineer and International Engineering

Several papers will be presented on the subject of opportunities for American management engineers in other countries.

Industrial Instruments and Regulators (II)—Aviation (II)

An Instrument for Indicating the Amount of Gas in Gas-Liquid Mixtures, by B. R. Walsh and G. S. Peterson, Gulf Research & Development Co., Pittsburgh, Pa.

Design Details of a Device for Measuring the Radial Pressure Distribution of Piston Rings, by an engineer of the Gulf Research & Development Co., Pittsburgh, Pa.

Electronic Instruments for Industrial Processes, by P. S. Dickey and A. J. Hornbeck, Bailey Meter Company, Cleveland, Ohio

Applied Mechanics (II)

Direct Analysis of Mechanical Wave Filters, by R. C. Binder, Purdue University, Lafayette, Indiana*

Dynamics of an Elastic Bar, by O. R. Wikander, Edgewater Steel Co., Pittsburgh, Pa.*

Basic Mechanics of the Metal-Cutting Processes, by M. E. Merchant, Cincinnati Milling Machine Co., Cincinnati, Ohio*

An Experimental Investigation of Turbulence Diffusion—A Factor in the Transportation of Sediment in Open Channel Flow, by E. R. Van Driest, Massachusetts Institute of Technology, Cambridge, Mass.*

Hydraulics (II)

Analysis by the Laplace-Mellin Transformation, by G. R. Rich, Tennessee Valley Authority, Knoxville, Tennessee

Water-Hammer Problems in Connection With the Design of Hydroelectric Plants, by E. B. Strowger, hydraulic engineer, Buffalo, Niagara & Eastern Power Corporation, Buffalo, N. Y.

Metals Engineering (II)

Fatigue Strength of $5^1/_4$ Diameter Shafts as Related to Design of Large Parts, by O. J. Horger, T. V. Buckwalter, and H. R. Neifert, Timken Roller Bearing Company, Canton, Ohio

TUESDAY (*continued*)

2:30 p.m.

Relative Cost of Castings and Welded Structures in Diesel-Engine Design, by L. F. Williams, Bessemer Corporation, Mt. Vernon, Ohio

Recent Developments in Engineering Materials, by Archibald Black, Simmonds Aerocessories, Inc., New York, N. Y.

5:00 p.m.

Forest Fires Conference

Conference Between representatives of Society of American Foresters and A.S.M.E. on subject of Forest Fire Fighting Equipment

8:00 p.m.

Management (V)

New Horizons for the Engineer in Distribution

Three outstanding industrialists will discuss the subject from the point of view of company and top-management policy to be followed by prepared discussions and comments from the floor

Power (II)

Paper contributed by the Navy on the Mobile Power Plants

Boiler Nozzles and Valve Inlets for High Capacity Safety Valves, by E. K. Falls, instructor, department of mechanical engineering, Clarkson College of Technology, Potsdam, N. Y., and Peter A. Ibold, development engineer, Manning, Maxwell and Moore, Bridgeport, Conn.

Furnace Performance Factors

External Corrosion of Furnace Wall Tubes: (1) History and Occurrence, by W. T. Reid, U. S. Bureau of Mines, Pittsburgh, Pa., R. C. Corey, and B. J. Cross, Combustion Engineering Company, New York, N. Y.

External Corrosion of Furnace Wall Tubes: (2) Significance of Sulphate Deposits and Sulphur-Trioxide in Corrosion Mechanism, by R. C. Corey, B. J. Cross, Combustion Engineering Company, New York, N. Y., and W. T. Reid, U. S. Bureau of Mines, Pittsburgh, Pa.

Applied Mechanics (III)

A Simplified Method of Determining Hoop Stresses in Fan Rotors, by G. F. Lake, Imperial Chemical Industries, Billingham, England*

Concentrated Force Problems in Plane Strain, Plane Stress, and Transverse Bending of Plates, by P. S. Symonds, Naval Research Laboratory, Anacostia Station, Washington, D. C.*

(*Program continued on following page*)

TUESDAY (*continued*)

8:00 p.m.

Distribution of Load in a Gear Set, by H. Poritsky, A. D. Sutton, and A. Pernick, General Electric Company

The Effect of Transverse Shear Deformation on the Bending of Elastic Plates, by E. Reissner, Massachusetts Institute of Technology, Cambridge, Mass.*

WEDNESDAY, NOVEMBER 29

9:30 a.m.

Applied Mechanics (IV)

Inelastic Buckling of Variable Section Column, by Dana Young, University of Texas, Austin, Texas*

Yielding and Fracture of Medium-Carbon Steel Under Combined Stress, by E. A. Davis, Westinghouse Research Laboratories, East Pittsburgh, Pa.

A New Design Criterion for Wire Rope, by D. C. Drucker and H. Tachau, Armour Research Foundation, Chicago, Ill.*

Stresses in a Cylindrical Shell Due to Nozzle or Pipe Connection, by G. J. Schoessow and L. F. Kooistra, The Babcock & Wilcox Co., Barberton, Ohio*

Power (III)

Symposium on Dust Collection, pertaining generally to equipment as made by various manufacturers

Management (VI)

New Horizons for the Engineer in Agriculture

Boiler Feedwater Studies

Silica Deposition in Steam Turbines, by F. G. Straub, research professor of chemical engineering, and Hilary A. Grabowski, chemical-engineering department, University of Illinois, Urbana, Ill.*

History of Potassium Treatment at Springdale Station, by L. E. Hankison, efficiency superintendent, West Penn Power Co., Pittsburgh, Pa., and M. D. Baker, chief chemist, West Penn Power Co., Springdale, Pa.

Experience With Potassium Treatment at Montaup Station, by George V. Parks, Montaup Electric Co., Fall River, Mass.

Experience With Potassium Treatment at Windsor Station, by W. L. Webb, American Gas and Electric Service Corporation, New York, N. Y.

Heat Transfer (I)

Symposium on Extended-Surface Heat Exchangers (1)

Aircraft Supercharger Intercoolers, by L. P. Saunders, Harrison Radiator Division, General Motors Corporation, Lockport, N. Y.

(WEDNESDAY *continued*)

9:30 a.m.

Heat Transfer From Baffled Finned Cylinders, by A. W. Lemmon, Jr., research assistant, A. P. Colburn, professor of chemical engineering, department of chemical engineering, University of Delaware, Newark, Del., and H. B. Nottage, assistant project engineer, Pratt & Whitney Aircraft, Hartford, Conn.

Local Coefficients of Heat Transfer for Air Flowing Around a Finned Cylinder, by W. H. McAdams, R. E. Drexel, and R. H. Goldey, Massachusetts Institute of Technology, Cambridge, Mass.

Efficiency of Extended Surface, by Karl A. Gardner, The Griscom-Russell Co., New York, N. Y.

12:30 p.m.

Student Luncheon
Aviation Luncheon

2:30 p.m.

Metals Engineering (III)—Production Engineering (II)

Trend in the Use of Welded Machinery Parts, by E. J. Charlton, assistant to the president, Lukenweld, Inc., Coatesville, Pa.

Paper on Machining Welded Crankcases

Railroad (I)—Oil and Gas Power (I)

Gas-Turbine Locomotive for Main-Line Service, by Paul R. Sidler, resident engineer, Brown, Boveri & Co., New York, N. Y.*

A Gas-Turbine Road Locomotive, by J. T. Rettaliata, manager, research and gas-turbine development division, Allis-Chalmers Manufacturing Co., Milwaukee, Wis.*

Heat Transfer (II)

Symposium on Extended-Surface Heat Exchangers (2)

Tube Spacing in Finned Tube Banks, by S. L. Jameson, General Electric Co., Schenectady, N. Y.

A General Correlation of Friction Factors for Various Types of Surfaces in Crossflow, by A. Y. Gunter, director of development, and W. A. Shaw, development engineer, American Locomotive Co., Alco Products Division, New York, N. Y.

Air-Cooled Steam Condensers, by R. A. Bowman, manager, condenser engineering department, Westinghouse Electric & Manufacturing Company, Philadelphia, Pa.

WEDNESDAY (*continued*)

2:30 p. m.

Aviation (III)

Postwar Aviation and Its Effect on Our Industrial, Economic, and Social Life

Speakers: T. P. Wright, Director of Civil Aeronautics Administration, Washington, D. C.

William B. Stout, director, Stout Research Division, Consolidated-Vultee Aircraft Corporation, Dearborn, Mich.

Fred E. Weick, chief engineer, Engineering and Research Corporation, Riverdale, Md.

6:30 p.m.

Annual Dinner

THURSDAY, NOVEMBER 30

9:30 a.m.

Education for Management

An Experiment in Management Education, by R. C. Muir, vice-president in charge of engineering and assistant to the president, General Electric Company, Schenectady, N. Y.

The paper describes a course in business management which is being currently given to employees at the management level. The course is unique in that it is carried on by the participants themselves and breaks away from academic procedures. The curriculum was prepared by a pilot group led by the author

Upper Management in Training, by Guy R. Cowing, assistant director, General Motors Institute, Flint, Michigan

It is proposed to give an analysis of training in this field of development out of the years of experience of General Motors Institute in acting as a central training agency for General Motors Corporation

Heat Transfer (III)

Symposium on Extended-Surface Heat Exchangers (3)

Heat Transfer Through Tubes With Integral Spiral Fins, by D. L. Katz, K. O. Beatty, Jr., and A. S. Foust, department of engineering research, University of Michigan, Ann Arbor, Michigan

Heat Transfer and Pressure Loss in Small Commercial Shell and Finned Tube Heat Exchangers, by R. M. Armstrong, Downington Iron Works, Inc., Downington, Pa.

The Economics of Individual Serrated Finned Surface, by E. A. Schryber, Extended Surface, Inc., Brooklyn, N. Y.

Railroad (II)

Progress in Railway Mechanical Engineering*

(*Program continued on following page*)

THURSDAY (*continued*)

9:30 a.m.

Report of Committee RR-6, Survey, by E. G. Young, chairman, K. F. Nystrom, B. S. Cain, E. R. Battley, and H. C. Wilcox

Practical Aspects of Feedwater Treatment for Locomotive Use, by Thomas H. Hislop, water engineer, New York Central System

Carry-Over in Locomotive Boilers, by Arthur Williams, chief engineer, Superheater Company*

Report of Technical Committee on Locomotives, by Lawford H. Fry, director of research, The Locomotive Institute, New York, N. Y.

Load-Compensating Air Brakes, by C. D. Stewart, director of engineering, Westinghouse Air Brake Co., Wilmerding, Pa.*

Metal Cutting (I)

Tool Control Practiced at Puget Sound Navy Yard, by W. E. Ainsworth, master mechanic, tool shop, Puget Sound Navy Yard, Bremerton, Wash.*

Survey on Tipping of Tools for Purpose of Conservation of Cutting Tool Material, by Frank J. Oliver, technical editor, *The Iron Age*, New York, N. Y.

Some New Phases in the Use of Cutting Tools, by W. L. Kennicott, engineer, Kennametals, Inc., Latrobe, Pa.

Diamond Cutting Tools, by Paul Grodzinski, mechanical engineer, The Diamond Trading Co., Ltd., research department, St. Andrews House, London, E. C. 1, England

Aviation (IV)—Oil and Gas Power (II) Jet Propulsion

Gas Turbine and Jet Propulsion Engines, by D. F. Warner, assistant design engineer, Supercharger Engineering Division, General Electric Company, Lynn, Mass.

Gas Turbine in Aviation—Its Past and Future, by S. R. Puffer, supercharger engineering department, General Electric Company, Lynn, Mass.

Process Industries (I)

Paper on Bone Char Research

Paper on Evaporation

Rubber and Plastics (I)

Creep Properties of Molded Phenolic Plastics at Elevated Temperatures, by W. J. Gailus, research investigation engineer, and David Telfair, plastics division, Monsanto Chemical Company, Springfield, Mass.

The Use and Evaluation of Some Specialty Adhesives, by Fred Wehmer, technical director, adhesive division, Minnesota Mining & Manufacturing Company, St. Paul, Minn.

THURSDAY (*continued*)

9:30 a.m.

Effect of Some Environmental Conditions on the Permanence of Cellulose Acetate and Cellulose Nitrate Sheet Plastics, by T. S. Lawton, Jr., and H. K. Nason, plastics division, Monsanto Chemical Company, Springfield, Mass.

12:30 p.m.

Railroad Luncheon

2:30 p.m.

Heat Transfer (IV)

Symposium on Extended-Surface Heat Exchangers (4)

Disk Extended Surfaces for High Heat Absorption Duty, by G. E. Tate and John Cartinhour, Foster Wheeler Corporation, New York, N. Y.

Heat Flux Pattern in Fin Tubes Under Radiation, and Relative Efficiency of Fin Tubes in Convection Zone, by A. R. Mumford, research and development department, and E. M. Powell, engineering department, Combustion Engineering Co., Inc., New York, N. Y.

Heat-Transfer and Pressure Drop of Liquids in Double Pipe Fintube Exchangers, by B. De Lorenzo, manager, heat-transfer department, and E. D. Anderson, design engineer, Brown Fintube Co., Elyria, Ohio

Railroad (III)

Stresses in Passenger Cars Derived From End Loads, by Allan Clark, assistant general mechanical engineer, American Car & Foundry Co.

Critical Shearing Stress in Skin-Stressed Boxcar Sides, by V. L. Green and J. J. Drinka, Chicago, Milwaukee, St. Paul & Pacific Railroad

Passenger Car Trucks, by K. F. Nystrom, mechanical assistant to chief operating officer, Chicago, Milwaukee, St. Paul & Pacific Railroad

Freight-Car Trucks, by R. B. Cottrell, chief mechanical engineer, American Steel Foundries

Metal Cutting (II)

Relation of Surface Roughness Readings to Actual Surface Profile, by Leo P. Tarasov, research engineer, Norton Company, Worcester, Mass.*

New Developments Made Possible by Plunge Form and Thread Grinding and the Crush Dressing of Grinding Wheels, by W. Fay Aller, director of research, Sheffield Corporation, Dayton, Ohio*

Cutter Grinding—A Prerequisite to Milling Steel With Carbides, by Fred W. Lucht, development engineer, The Carboloy Company, Detroit, Mich.

THURSDAY (*continued*)

9:30 a.m.

Methods of Mechanically Mounting Cutting Blades of Solid Cemented Carbide, by W. L. Kennicott, engineer, Kennametals, Inc., Latrobe, Pa.

Rubber and Plastics (II)

Advances In Rubber and Plastics in 1944, by W. J. Liska, Firestone Tire & Rubber Co., Akron, Ohio, and Gordon M. Kline, Chief, Organic Plastic Section, National Bureau of Standards, Washington, D. C.

Creep and Relaxation in Rubber Products, by R. D. Andrews and A. V. Tobolsky, department of chemistry, Princeton University, Princeton, N. J.

Safety—Management (VII)

What Engineering Societies Can Do to Encourage Safety Education in Technical Colleges and High Schools, by Walter Cutter, Center for Safety Education, New York University, New York, N. Y.

The Hiring of Handicapped Military Personnel, by Michael Supa International Business Machines Corporation, New York, N. Y.

Panel Discussion on Training for Safe Machine Operation:

Discussion Leader: S. W. Mudge, War Manpower Commission, New York, N. Y.

Members of Panel:

- R. S. Bonsib, Standard Oil Co., New York, N. Y.
- A. G. Bugenstock, Western Electric Company, Kearny, N. J.
- William Heinrich, Travelers Insurance Company, Hartford, Conn.
- W. H. Hollis, Sperry Gyroscope Co., Inc., Brooklyn, N. Y.
- F. C. Lillienthal, American Type Founders, Elizabeth, N. J.
- W. H. Richardson, Air Reduction Sales Co., New York, N. Y.

Aviation (V)—Oil and Gas Power (III)

Lubrication Ceiling, by P. H. Schweitzer, professor of engineering research, The Pennsylvania State College, State College, Pa.

Optimum Compression Ratios for High-Speed Diesel Engines, by W. P. Green, associate professor of mechanical engineering, University of Maryland, College Park, Maryland*

8:00 p.m.

Power (IV)

Symposium on Metallurgy of Marine Engineering, with six- to ten-minute discussion by prominent engineers of manufacturers of marine equipment

(*Program continued on following page*)

THURSDAY (*continued*)

8:00 p.m.

Metal Cutting (III)—Production Engineering (III)

A Study of Some Fundamentals When Milling Steel With Carbides, by Fred W. Lucht, development engineer, The Carboloy Company, Detroit, Mich.

The Influence of the Application of Cutting Fluids at Different Temperatures When Turning Steel, by O. W. Boston, W. W. Gilbert, and R. E. McKee, department of metal processing, College of Engineering, University of Michigan, Ann Arbor, Mich.*

A Thermal Balance Method and Mechanical Investigation for Evaluating Machinability, by A. O. Schmidt, research engineer, Kearney & Trecker, Inc., Milwaukee, Wis., O. W. Boston, and W. W. Gilbert, department of metal processing, University of Michigan, Ann Arbor, Mich.*

Helical Taper Reamers Milled With Constant Helix Angle, by T. F. Githens, mechanical engineer, Cleveland Twist Drill Co., Cleveland, Ohio*

Education of Returning Service Man

A Pattern for the Broadening Elements of the Curriculum, by Dean C. J. Freund, University of Detroit, Detroit, Mich.

Apprentice Training After the War, by William F. Patterson, director of apprentice training service, War Manpower Commission, Washington, D. C.

Technical Institute Training, by Mark Ellingson, president, Rochester Institute of Technology, Rochester, N. Y.

THURSDAY (*continued*)

8:00 p.m.

Heat Transfer (V)

Panel Discussion on High Speed Heating Times, Techniques, and Uniformities. Fuel-Fired Techniques and Their Possibilities, by F. O. Hess, president, Selas Corporation of America, Philadelphia, Pa.

Temperature Uniformity in Heating Slabs up to 3000 F, by Victor Paschkis, research associate, department of mechanical engineering, Columbia University, New York, N. Y.

Induction Heating Techniques, With Frequency Analyses and Notes on High Power Concentrations, by Wesley M. Roberts, Commercial and Industrial Equipment, Radio Corporation of America, Camden, N. J.

FRIDAY, DECEMBER 1

9:30 a.m.

Council Meeting

9:30 a.m.

Aviation (VI)—Applied Mechanics (V)

On Fatigue Failure Under Triaxial Static and Fluctuating Stresses and a Statistical Explanation of Scale Effect, by F. H. Fowler, Jr., senior structures engineer, Curtiss-Wright Corporation, Propeller Division, Caldwell, N. J.

An Acceleration Damper, by Paul Lieber, supervisor of flutter and dynamic analysis group, Douglas Aircraft Company, Santa Monica, California

Fatigue Tests of Airplane Generator Brackets With Special Reference to Failure of Screw Fastenings, by A. M. Wahl, Westinghouse Research Laboratories, East Pittsburgh, Pa.*

Cushing, N. Y.

THE LAST TIME ALL THE "BIG BOATS" WERE IN TOGETHER

(View of upper Manhattan docks from cliffs of New Jersey.)

Official Notice

A.S.M.E. Business Meeting

THE Annual Business Meeting of the members of The American Society of Mechanical Engineers will be held on Monday afternoon, November 27, 1944, at 4:00 p.m. at the Pennsylvania Hotel, New York, N. Y., as a part of the Annual Meeting of the Society.

FRIDAY (*continued*)

9:30 a.m.

Measurement of Torque Transmitted by Rotating Shafts, by B. F. Langer, Westinghouse Research Laboratories, East Pittsburgh, Pa.*

Heat Transfer (VI)

Panel Discussion on Measurement of Heat Absorption in Furnaces
Eight speakers on Boiler Furnaces
Four speakers on Industrial Furnaces

Materials Handling (I)—Management (VIII)—Production Engineering (IV)

Three - Dimensional Planning—New Trends in Industrial Plant Layout, by R. W. Mallick, industrial engineer, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

Panel Discussion on Plant Layout for Industrial Reconversion

Textile

The Influence of Ring Size Bobbin Diameters and Spindle Speed on the Spinning of Yarn, by A. N. Sheldon, F. P. Sheldon & Son, Providence, R. I.

The Engineering Properties of Mechanical Felts, by William Lehmberg, American Felt Company

12:30 p.m

Textile Luncheon

2:30 p.m.

Heat Transfer (VII)

Papers on Heat Transfer

Effect of Temperature, Metals

Graphitization of steel piping

Graphitization of Low Carbon and Low-Carbon-Molybdenum Steels, by Howard J. Kerr, executive assistant research, and F. Eberle, Metallurgist, Babcock & Wilcox Co., New York, N. Y., and Barberton, Ohio

Progress Report on Graphitization of Steam Lines, by S. L. Hoyt, technical advisor, and R. D. Williams, welding engineer, Battelle Memorial Institute, Columbus, Ohio

(*Program continued on following page*)

FRIDAY (*continued*)

2:30 p.m.

Investigation of Graphitization at Detroit, by R. M. Van Duzer, Jr., I. A. Rohrig, and Arthur McCutchan, engineering division, The Detroit Edison Co., Detroit, Mich.

A Study of Austenitic Welding for Control of Graphitization, by I. A. Rohrig, engineering division, The Detroit Edison Company, Detroit, Mich.

Materials Handling (II)

Clinic on materials-handling aids in modern production

Aviation (VII)—Applied Mechanics (VI)

Some Fundamentals of Fuselage Frame Design, by J. E. Wignot, stress analysis department, Lockheed Aircraft Corporation, Factory "B," Burbank, California

Efficiency of Wing Tension and Compression Covers, by A. F. Donovan, Curtiss-Wright Research Laboratory, Buffalo, N. Y.; Martin Goland, section head, Structural Design, Curtiss-Wright Laboratory, Buffalo, N. Y.; and J. N. Goodier, professor of mechanics, Cornell University, Ithaca, N. Y.*

Bending of Curved Thin Tubes, by L. Beskin, Consolidated Vultee Aircraft Corporation, San Diego, California*

Some Applications of Welded Aircraft Tubing, by J. S. Adelson, chief metallurgist, and E. Park Hill, chief process and inspection engineer, steel and tubes division, Republic Steel Corporation, Cleveland, Ohio

Process Industries (II)

Papers on All-Year-Round Air Conditioning—one dealing with absorption and the other with compression

Cushing, N. Y.

SHOWING ROCKEFELLER CENTER AT NIGHT

Preprints of 1944 Annual Meeting Papers

As usual, a considerable number of papers to be presented at the 1944 A.S.M.E. Annual Meeting to be held at the Pennsylvania Hotel, New York 18, N. Y., Nov. 27 to Dec. 1, 1944, will be available in preprint form for distribution.

The program of the Meeting which appears on pages 740–745 of this issue indicates the papers to be ready (so far as is known at press date) for distribution a week to 10 days in advance of the Meeting. A few additional papers, received too late for preprinting in advance of this issue date, will be available at the sessions. So long as stock lasts, orders will be filled, but we cannot guarantee delivery in advance of the meeting.

Charges for preprints ordered by mail range from 15 to 30 cents a copy, depending on the number of pages (10 to 25 cents if purchased at publication booth). However, since it is not possible to state at this writing the number of pages in these papers, we suggest that fifteen cents be forwarded for each preprint which is ordered. If remittance is insufficient, bill will be rendered for the difference.

Orders accompanied by remittance should be sent to A.S.M.E. Headquarters, 29 West 39th St., New York 18, N. Y.

Registration Fee for Non-Members at the 1944 Annual Meeting

There will be a registration fee of $2 for nonmembers attending the 1944 Annual Meeting. For nonmembers wishing to attend just one session (except evening sessions or meal meetings) the fee will be $1. This is in accordance with the ruling of the Standing Committee on Meetings and Program.

Members wishing to bring nonmember guests (male) may avoid this fee by writing to the Secretary of the Society before November 17 asking for a guest-attendance card for the Annual Meeting. The card, upon presentation by a guest, will be accepted in lieu of the registration fee. Guests are limited to *two per member*.

A.S.M.E. Medals and Honorary Memberships to Be Conferred at the Coming 1944 Annual Meeting

At the Annual Meeting of The American Society of Mechanical Engineers to be held at the Pennsylvania Hotel, New York, N. Y., Nov. 27–Dec. 1, 1944, awards and honors for the year 1944 will be conferred, with the customary impressive ceremonies. Recipients of awards and honors are as follows:

Honorary Membership to Charles M. Allen, professor of hydraulic engineering, Worcester Polytechnic Institute.

To Major General Levin H. Campbell, Jr., Chief of Ordnance, United States Army.

To Rear Admiral Emory S. Land, U. S. N. (Retired), Chairman, United States Maritime Commission.

To Gano Dunn, president, J. G. White Engineering Corporation, New York, N. Y.

To Sir Standen Leonard Pearce, engineer in chief, London Power Co., Westminster, London, England.

A.S.M.E. Medal to Edward G. Budd, president of the Budd Manufacturing Company, Philadelphia, Pa., "because of his outstanding engineering achievements. He was a pioneer in the development of the welded all-steel automobile body and the steel-disk automobile wheel. He also pioneered development of the "shotwelding" process which made practical the use of stainless steel in structures, such as railroad passenger-train cars, bus and truck bodies, and airplanes. He was the leader in the construction of streamlined lightweight railroad passenger trains with their many innovations. In connection with his development of the steel automobile body, he perfected the design of many intricate dies for forming sheet steel by deep-drawing. His reputation for fine Christian character is as outstanding as it is for engineering."

The Holley Medal to Carl L. Norden of Carl L. Norden, Inc., New York, N. Y., "for the invention and development of the Norden bombsight and other valuable devices which should hasten the peace."

Worcester Reed Warner Medal to Earle Buckingham, professor of mechanical engineering, Massachusetts Institute of Technology, Cambridge, Mass., "for his original contributions to engineering literature, especially in the fields of interchangeable manufacturing and gearing, based no less on his extensive research work than on his broad experience in many fields of practical manufacturing. His group of books on gear design, production, and application are outstanding in this field of mechanical engineering."

Spirit of St. Louis Medal to George W. Lewis, Director, Aeronautical Research, National Advisory Committee for Aeronautics, Washington, D. C., "for leadership in direction and encouragement of aeronautical research, having an extensive influence on aeronautical engineering during the past quarter century."

Charles T. Main Award to Fred M. Piaskowski of the University of Detroit, and Detroit, Mich., for his paper "A Case Study of Labor-Management Co-Operation."

Undergraduate Student Award to Nelson B. Hammond of the University of Pennsylvania, and Philadelphia, Pa., for his paper "An Investigation of Silver-Solder Penetration in Brass Joints."

President's Page

Our Immediate Responsibilities

THE engineering profession is taking a larger part in this war than engineers ever took in any previous war—both on the fighting lines and on the production lines. More than ever, also, the readjustment to an enduring peace will require the constructive work of engineers. The engineering societies are moving to accept their share of this responsibility.

First, we are giving attention to the personal readjustments involved in release of large numbers from military service and in change-over from wartime to peacetime production. That problem is already with us; it did not wait for the end of the war. I hope all our members at home will read the letter on page 747 that has been sent to our members who are in the armed services because your interest and your co-operation are likewise solicited and urgently needed. This war must not result in a lost generation of engineers. We can have instead a splendid generation of engineers, qualified by their war experience and the postwar opportunities we offer them to reach a new high level of service to industry and society.

Second, we are giving attention to such postwar arrangements as will affect the productivity of world industry to meet world needs. The use of that productivity, the planning to meet those needs, will be largely an engineering task. American engineers are concerned with it. Without venturing into complex questions of diplomacy and international policy, the presidents of five engineering societies have offered a program for the selective restriction and control of German industry, which you may read on page 748. In the engineering profession we are particularly aware of the contributions that the German nation, freed from the domination of war lords, can make to the world in the future in technology and in scientific and industrial advance. The proposed program, we believe, affords ample insurance against war, while avoiding the creation of an economic vacuum which could not long endure.

The engineering talents of the nation are being used effectively in the war-making agencies of our government for winning the war. They can be of great service, also, in its peacemaking agencies to help make a durable peace. We hope that this program will stimulate realistic thinking among our members and elsewhere toward the end we seek.

(*Signed*) R. M. GATES, *President*, *A.S.M.E.*

(At a meeting on Oct. 17, 1944, the Executive Committee of the A.S.M.E. Council voted approval of the letters and statement mentioned in Mr. Gates's message.—Editor.)

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

TWENTY-NINE WEST THIRTY-NINTH STREET

NEW YORK

October 19, 1944

OFFICE OF THE PRESIDENT
60 EAST 42ND STREET
NEW YORK 17, N. Y.

To: A.S.M.E. Members in the Armed Forces:

The sheer numbers of you, over 3000, in the Armed Forces make it impossible to address each of you in the personal way I would like. While the appearance of this letter may be stereotyped, its spirit is that of a real and personal interest in the success of each one of you.

Your colleagues in engineering on the home front are devoting their waking hours to the production of your needs but in their spare opportunities they are concerning themselves with the many problems we shall face in the shift from war to peace. The engineering profession is in the midst of this whirl of change -- from a war of mechanized industries as well as mechanized armies, to a peace more than ever dependent on the constructive work of engineers. How can our Society give the best service to its members in this readjustment -- to all its members, but especially to you who are in the war services, whose professional careers have been interrupted by the war?

Many of you are far away. Others who are near are unable to keep in touch with our activities. For that reason we are sending this letter to every member shown by our records to be in war service; it will be published also in the November issue of Mechanical Engineering.

Some of you will return to college. Others will take positions with former employers. But many will want to start anew.

We are encouraging both industrial management and educational institutions to keep in touch with you and to give full, active support to programs of advanced training and replacement of personnel. The professional societies will endeavor to supplement their activities and fill the gaps.

We want your suggestions of what we can do for you, and what we can do as a Society in regard to the whole problem of readjustment.

Let me assure you of our best wishes in your present service and for your future career.

Cordially yours,

R. M. Gates

R. M. Gates
President

Facsimile of letter referred to in Mr. Gates's message, page 746

Presidents of Five Engineering Societies Suggest Program for Industrial Control of Postwar Germany

ON October 2the presidents offive national engineering societies—the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the American Institute of Chemical engineers—sent to the Secretary of State the following letter relating to technical and industrial problems involved in the permanent disarmament of Germany:

Text of Presidents' Letter to the Secretary of State

Dear Mr. Secretary:

Recognizing the technical and industrial problems involved in the permanent disarmament of Germany, the presidents of the above listed engineering societies initiated discussions on this subject in March, 1944, with many members of the profession. Since that time we have continued the studies of this problem.

We are enclosing herewith the first draft of a paper dealing with this subject. We realize fully that the procedures suggested from an engineering viewpoint have not been fully considered with and co-ordinated with the international political problems involved. We believe that the proper integration of the political with the engineering aspects of the whole problem of postwar Germany is essential.

We should like an appointment with you at your convenience to discuss these matters.

Very truly yours,

MALCOLM PIRNIE, *President*, American Society of Civil Engineers

CHESTER A. FULTON, *President*, American Institute of Mining and Metallurgical Engineers, Inc.

R. M. GATES, *President*, The American Society of Mechanical Engineers

C. A. POWEL, *President*, American Institute of Electrical Engineers

G. G. BROWN, *President*, American Institute of Chemical Engineers

Text of Suggested Program

THE destruction of the plants, machines, utilities, tools, materials, and other essentials for peacetime living penalizes not only the owners of the materials destroyed, but the world as a whole.

Specifically, the fundamental fallacy of any proposal for the indiscriminate destruction of the German industrial system is that it fails to differentiate between the wartime and the peacetime economy of the Reich.

We are for one, simple, clear objective—an effective industrial means to keep Germany from starting another war.

This objective should not be confused, especially before the war is even won, with the appropriate punishment of Germany or with the international arrangements for the long future to be made around the peace table by the representatives of the Allied Nations after victory is achieved.

This paper, therefore, does not deal with broad, complex, postwar questions of diplomacy and international policy.

What "Unconditional Surrender" Implies

"Unconditional surrender" implies disarmament of the German armies, the surrender of all arms, munitions, airplanes, and other ordnance matériel in stock piles or in process. It also should include the elimination of all German war-production facilities such as ordnance plants, munitions plants, submarine works, etc., and the control of raw materials required by war industries.

We make no suggestions as to the over-all international treatment of Germany after surrender, but confine our statement to the permanent physical disarmament of Germany and to the subsequent steps to make it impossible for her to prepare industrially for another war.

With this sole aim in view, however, we must recognize that the German nation cannot arbitrarily be kept in economic and industrial subjugation. To do so would create an economic vacuum in Europe which sooner or later would be filled, either by the German nation itself or by the collaboration of Germany with other nations or individuals who would profit financially or politically, or both, by helping to develop Germany into a good market.

Germany must have its chance for recovery along peaceful lines after the war. Such recovery cannot come about through an economy wholly agricultural, even if that were practicable; or without industry to produce both for German needs and for the reconstruction of other nations of Europe; or without markets.

Germany must be disarmed and that part of its industrial plant devoted to armament destroyed. But it is equally necessary to create a plan which will (*a*) allow the German people to live a reasonably normal life; (*b*) permit the retention of peacetime German industry and (*c*) keep an economic balance in Europe.

This, we are confident, can be done without giving German industry the independence it would require to prepare for war again, either secretly or overtly.

We recommend, therefore, not an indiscriminate destruction, but a selective restriction and control of German industry.

Germany and Europe and the world need the contributions which the German nation, freed from the domination of war lords, can make in the future, as it has made in the past, to the development of modern technology and scientific and industrial advance.

If Allied controls force the German people into an unnatural existence and hold back national economic development in Europe, they will become even more unstable and subject to pressures and possibilities containing the explosive seeds of another war. We should plan, therefore, to create a minimum of controls and to avoid abnormal social dislocations.

Discriminating between peace and war economy, there are at least four industries which are the most essential for war purposes, and the least essential for a peacetime economy. They are: Synthetic gasoline, for which there is no economical peacetime use; nitrogen fixation; special and high-alloy steels; and airplane production, all of which must be vastly expanded to prepare for war.

The labor employed by all these four industries in peacetime is less than two per cent of the total German labor force.

Steps to Take

Therefore, Germany's capacity to make war would be eliminated by the following steps in regard to its industrial economy:

1 Eliminate all synthetic-oil capacity and prohibit the reconstruction of plants and the importation of oil beyond normal peacetime inventories.

This would destroy the major part of Germany's internal oil resources. Coal is the raw material for synthetic oil. It is plentiful in Germany and only a small per cent is used in synthetic-oil plants. It is not readily controllable in the Reich.

2 Eliminate 75 per cent of Germany's synthetic-nitrogen-plant capacity and prohibit reconstruction of plants and all importation of nitrogen compounds. This will leave a capacity in Germany ample for peacetime nitrogen requirements. The principal ingredient of explosives is nitrogen. The relatively small amount of dynamite required for mining, quarrying, etc., should be under import control. Control imports of Chilean nitrates.

3 Eliminate 50 per cent of Germany's steelmaking capacity in those categories of plants which are most capable of producing essential war materials such as heavy forging and high-alloy steels. Control imports of manganese, chromium, nickel, and tungsten which are practically nonexistent in Germany. Also prohibit importation of iron ore, flux material, steel, and steel products beyond normal peacetime inventories.

4 Eliminate aircraft plants and equipment. Aluminum and magnesium are the raw materials required for airplane manufacture. There are no important bauxite deposits in Germany. Importation should be prohibited. Alumina and aluminum plants should be destroyed and importation of aluminum ingots beyond prewar peacetime needs be prohibited.

If any *one* of these steps were taken, war could not be waged nor prepared for. Taking all four would afford ample insurance against war.

By attacking the problem from this angle, it would be possible to set up uncomplicated, nonpolitical controls to prevent the rearmament of Germany, but at the same time make it possible for the German nation to meet its own peacetime needs and thereby prevent her from becoming a drag on the economy of all Europe and a breeder of future wars.

Fifty or sixty per cent of all the German oil and gasoline supplies have come from synthetic-coal-distillation plants scattered throughout Germany. A third of her requirements have been derived from the Ploesti oil field in Rumania. The synthetic plants produce inferior products at a cost about four times world prices. Their operation has required government subsidy. These war plants should be demolished.

Eighty per cent of nitrogen is produced synthetically from the air, but it could not be produced without reconstruction of special plants or without Chilean nitrates which Germany must import.

Germany could not make steel, produce oil products, or make munitions of war without imports of bulky, easy-to-police materials. Hence policing the curtailment of potential war production would consist of (*a*) controlling the imports of, or the accumulation of stocks of, such bulk materials as petroleum, pyrites or brimstone, manganese, chrome or nickel, and iron ore, steel, aluminum, and nitrogen compounds, and (*b*) requiring periodic inspections of plants and special revocable permits of construction or of operation of manufacturing facilities for any purpose.

Further insurance could be secured by transferring the ownership or management of the remaining nitrogen and steel production plants into Allied hands.

When the Allied Nations have carried out the terms of unconditional surrender and have thereby rendered Germany harmless by disarmament for the next ten or fifteen years, a program of permanently disarming her must look not to 15 but to 50 years. It is unrealistic to assume that any program put forward to take the sting out of Germany will not require supervision and vigilance for a long period in the future.

The essence of this program is to remove from Germany the plant and source materials essential for war purposes, but to do it with the least disturbance to the normal economy of western Europe.

We do not believe that crippling the normal peacetime industrial economy of any country, even an enemy nation, can promote world peace and reconstruction. On the contrary, such a policy jeopardizes the peace and progress of all. We are opposed to any plan which would make postwar Germany a drag on the economy of all Europe, if not of the world, and a breeder of future wars.

Actions of A.S.M.E. Executive Committee

At Meeting Held at Society Headquarters, Sept. 25, 1944

A MEETING of the Executive Committee of the Council of The American Society of Mechanical Engineers was held at the Society headquarters, New York, N. Y., Sept. 25, 1944. There were present: R. M. Gates, chairman, W. J. Wohlenberg, vice-chairman, A. C. Chick, D. W. R. Morgan, and A. R. Stevenson, Jr., of the Committee; J. J. Swan (Finance), W. M. Sheehan (Professional Division), A. R. Mumford (Local Sections); H. V. Coes and R. F. Gagg, members of the Council; Alex D. Bailey, president-elect; C. E. Davies, secretary, and Ernest Hartford, executive assistant secretary.

The following actions were of general interest.

Election of Honorary Members

The following were declared elected honorary members of the Society: Charles M. Allen, Worcester, Mass.; Major General Levin H. Campbell, Jr., Washington, D. C.; Gano Dunn, New York, N. Y.; Rear Admiral Emory S. Land, Washington, D. C.; and Sir Standen Leonard Pearce, London, England.

Charles T. Main Award Fund

Appreciation was voted of contributions of $300 from Col. F. M. Gunby to the principal of the Charles T. Main Award Fund and of $12.50 each from Miss Alice A. Main, W. M. Hall, and W. F. Uhl for the current award.

Additional Awards for 1944

In addition to 1944 awards previously announced the Committee voted to approve the following awards:

Charles T. Main Award, to Fred M. Piaskowski, University of Detroit, Mich., for his paper, "A Case Study of Labor Management Co-operation."

Undergraduate Student Award, to Nelson B. Hammond, University of Pennsylvania, Philadelphia, Pa., for his paper, "An Investigation of Silver-Solder Penetration in Brass Joints."

E.I.C.-A.S.M.E. Consulting Engineering Co-Operation

On the recommendation of the Committee on Professional Divisions and the E.I.C.-A.S.M.E. Joint Co-Operative Committee, the Executive Committee voted to authorize the formation of an E.I.C.-A.S.M.E. Joint Committee on Consulting Engineering.

Manufacturing Engineering Committee

H. B. Lewis, former executive secretary of the Manufacturing Engineering Committee, was appointed a member of that committee.

Membership Development

It was reported that the Membership Development Committee had sent letters to 700 members dropped on April 14, 1944, for nonpayment of dues. It was announced that 142 members had been appointed to serve on a National Membership Development Committee. Each member of this committee has received a letter, accompanied by a proposed letter of approach to qualified applicants within their respective territories. In discussion of the subject by the Executive Committee it was the general opinion that membership development should be a strong continuing activity with a well-defined objective, a sound organization, clear-cut procedures, and the necessary staff to support it.

A.S.M.E. Lectureship

F. L. Wilkinson, Jr., was requested to introduce Dr. Lionel S. Marks at his first A.S.M.E. lecture, Charleston, W. Va., October 16, and J. A. Noyes was requested to introduce Dr. S. Timoshenko at his first A.S.M.E. lecture, Houston, Texas, November 9.

Status of Engineers

The Secretary reported the following appointments by the Joint Conference Committee of Presidents and Secretaries to the Joint Committee on the Status of Engineers: I. Melville Stein, chairman; William N. Carey, vice-chairman; P. T. Onderdonk, secretary.

Award to Lee N. Gulick

The request of the executive committee of the Philadelphia Section to present the Certificate of Award to Lee N. Gulick, retiring chairman of that section, was granted.

Death of M. E. Cooley

The death, on August 25, 1944, of Dean Mortimer E. Cooley, past-president and honorary member, was noted with regret. Past-president James W. Parker was designated honorary vice-president to represent the Society at the funeral services.

Appointments

The following appointments were approved:

Wood Industries Executive Committee, C. B. Lundstrom, to fill the unexpired term of H. S. Jones to December, 1947.

Research Procedure Committee of the Engineering Foundation, W. Trinks (reappointment for one year).

Gantt Medal Board of Award, Erwin H. Schell, to fill the unexpired term of F. A. Schaff to 1946.

Joint Fuels Meeting, Charleston, W. Va., Oct. 30-31, 1944, E. G. Bailey, honorary vice-president.

Norwich University, Northfield, Vt., inauguration of president, Oct. 9, 1944, A. A. Potter, honorary vice-president.

1944 Officers of A.S.M.E. Elected by Letter Ballot

AS reported by the tellers of election Erik Oberg, S. D. Sprong, and G. L. Knight, letter ballots received from members of The American Society of Mechanical Engineers were counted on Wednesday, Sept. 26, 1944. The total number of ballots cast was 5435; of these 148 were thrown out as defective.

Candidates	Votes for	Votes against
For President		
ALEX D. BAILEY	5271	16
For Vice-Presidents		
DAVID LARKIN	5275	14
JOHN E. LOVELY	5274	13
THOMAS S. MCEWAN	5268	19
For Managers		
DANIEL S. ELLIS	5277	10
A. J. KERR	5276	11
H. G. THIELSCHER	5268	19

The new officers will be introduced and installed in office during the Sixty-Fifth Annual Meeting of the Society to be held in New York, N. Y., Nov. 27 to Dec. 1, 1944.

Biographical sketches of the newly elected officers appear in the August, 1944, issue of MECHANICAL ENGINEERING, pages 557–560.

R. E. Flanders to Receive Hoover Medal for 1944

THE Hoover Medal Board of Award has announced that Ralph E. Flanders, past-president A.S.M.E., has been elected seventh recipient of the Hoover Medal (1944).

The Hoover Medal was formally instituted on April 8, 1930, to commemorate the civic and humanitarian achievements of Herbert Hoover, to whom the first award was made. Conrad N. Lauer, past-president A.S.M.E., created the award in 1929 with a gift of a trust fund which is held by the A.S.M.E. and administered by the Hoover Medal Board of Award.

Problems in Which Army Is Interested

Suggestions to Be Sent to National Inventors Council

IN the September, 1943, issue, page 692, was published a list of problems for which the United States Army wished suggested solutions. A second list was published in the June, 1944, issue, pages 431–432. A third list, recently received, is presented this month.

It is recognized that partially satisfactory solutions to most of the problems in the third list are already available. However, there is always need for and interest in an original and inventive approach.

Suggested solutions should be forwarded to the National Inventors Council, Department of Commerce, Washington 25, D. C.

The list follows:

1 A lightweight, reliable, simply installed thrustmeter for aircraft installation, combined with a torquemeter if possible.

2 A shock absorber that does not require the use of synthetic packing to retain the fluid in the strut.

3 Shimmyproof free-swiveling castered wheel and tire.

4 An accurate simple cable-tension reading instrument.

5 A control cable having a coefficient of expansion close to that of aluminum alloys used in the aircraft structures or an equivalent mechanism which will take up cable slack.

6 A high-precision low-friction bearing that does not involve the use of balls or rollers.

7 The development of a suitable shock mount to permit the installation of a gun camera to a caliber-0.50 machine gun to permit the photographing of objects during the time that the gun is being fired.

8 Small lightweight gasoline engine, either 2 or 4 cycle, capable of reasonable continuous operation utilizing 100-octane aviation gasoline, which may be started and operated at temperatures as low as —65 F. Rating should be between 1 and 5 hp.

9 An independently operated heating unit for sea-level operation, capable of continuous operation at —65 F for a period of 8 hr. Unit should weigh not more than 1 lb per 1000 Btu per hr output and must deliver clean nontoxic heated air.

10 A liquid or paste good for at least 12 hours' service which will prevent the formation of ice on airplane surfaces.

11 To determine methods of fabricating quartz hairsprings and diaphragms for use in watches, aneroid barometers, altimeters, airspeed indicators, and rate-of-climb indicators.

12 A device for the quick release of a cargo parachute from the cargo upon contact of the cargo with the ground. This is desirable to prevent the dragging of the cargo on the ground.

13 Positive parachute-opening-device to provide automatic opening at a definite altitude above the ground.

14 Improved form-fitting, flexible, comfortable parachute pack for reduced weight and bulk and with tendency toward premature release eliminated, also improved wearing qualities desirable.

15 Harness, improved quick-releasing hardware, reduction of weight and bulk, increase in comfort.

16 Low-cost aerial delivery parachutes. Must withstand 200 mph airspeeds.

17 Parachute drop test instruments. Load recorder for parachute openings. Precise time of opening and rate of descent means.

18 Parachute canopy redesign to reduce weight and bulk without impairing present performance.

19 A stable parachute, equal strength and simplicity of construction to present hemispherical type.

20 A release and exchange mechanism for two targets suitable for exchanging targets without loss of equipment at high speeds.

21 A tow-target "hit indicator" to indicate hits and the direction and magnitude of misses for fixed, flexible, and turret aerial-gunnery-practice fire.

22 A tow target capable of being towed at high speeds and producing a low drag.

23 An extra-flexible, high-strength, $^1/_8$-in-diam, target towing cable that will not "bird-cage."

24 Machine for running breakdown experiments on heating elements incorporated in electrically heated flying clothing. Clothing includes jackets, trousers, gloves, and shoes.

25 Design dependable thermostats for control of heating clothing to operate on direct current, small enough to be used in gloves and boots.

26 Development of an electroplating method for the deposition of a lead-indium alloy containing approximately 4 per cent indium.

27 Development of methods or apparatus for establishing the quality of glue joints in wood without testing to destruction.

28 Development of a material with the electrical properties and heat-resistant characteristics of mica.

29 Automatic ground-speed measuring devices.

30 Compact, light, and durable two-speed or variable drive for geared superchargers.

31 Shockless two-speed propeller drive mechanism.

32 Practical variable-diameter propeller to give maximum performance at S.L. and extreme altitude.

33 Practical two-position or variable-compression-ratio control.

34 Simple and light detonation indicator for installation in airplanes.

New Actions on Standards by A.S.T.M.

Many new specifications and tests for engineering materials and important changes in existing standards were approved on August 28 by the American Society for Testing Materials acting through its committee on standards procedure. Materials involved include steel forgings and castings, gray-iron castings, malleable-iron flanges, copper, electrical conductors, cement, clay pipe, soil cement mixtures, veneer, plywood, etc., glass insulators, and embrittlement-testing of boiler waters. In all, 15 new standards were approved for publication as tentative, and there were revisions in some 30 previously issued specifications.

Grinding Wheel Manufacturers Adopt New Standard

THE Grinding Wheel Manufacturers Association announced on Nov. 1, 1944, the adoption of "Standard Markings for Identifying Grinding Wheels and Other Bonded Abrasives." Shipment of grinding wheels bearing the new marking will commence December 1, 1944.

A previous standard was submitted and approved under American Standards Association procedure as an American Standard (B5.17–1943). As use of this standard was expanded, according to the "foreword" of the new publication, shortcomings were brought out.

The opinion of the committee of the Grinding Wheel Manufacturers Association assigned to study the subject was that the principal reason for the failure of the American Standard was "that confusion still existed and nowhere in the standard itself was it made clear that wheels similarly marked, if made by different manufacturers, would not grind alike."

The new standard is "a standard of markings only and not of grinding action." The best points of the previous standard were retained, other features not satisfactory were revised. The most important revision was the adoption of an alphabetical marking system, for all bond types, to designate grade of hardness. Better provision was made for the wheelmaker to incorporate into the markings such special symbols as might be required to properly qualify the basic symbols of the standard markings."

Copies of the standard may be obtained by addressing the Grinding Wheel Manufacturers Association, 27 Elm St., Worcester 8, Mass.

I.E.S. to Sponsor Lighting Research Program

THE Illuminating Engineering Society has announced establishment of the Illuminating Engineering Society Research Fund for the purpose of research in lighting and related subjects. Administration of the fund will be the exclusive responsibility of a Board of Trustees, consisting of the president and immediate past-president of the I.E.S., as ex-officio members serving for one year in each capacity, and five prominent scientists and businessmen interested in lighting, vision, and allied subjects. A Research Executive Committee of six, appointed by the Board, will report on the progress of the various researches and arrange for the publication of results. Individual research projects are expected to be carried out with the co-operation of the research laboratories of leading universities and other institutions.

Crouch Named Technical Secretary

It was also announced that Cazamer L. Crouch had been appointed full-time technical secretary of the I.E.S. As technical secretary Mr. Crouch will act as a consultant to the technical committees and to the I.E.S. and render assistance in the society's new research program. During the coming year his major assignment, the announcement says, will be the compilation, writing, and publication of an I.E.S. Illumination Design Handbook.

Committee on Industrial Furnaces and Kilns, A.S.M.E. Heat Transfer Division, Expands

During 1944 the Committee on Industrial Furnaces and Kilns of the A.S.M.E. Heat Transfer Division has expanded, both in personnel and in conception of purpose and function. This report therefore is submitted with the specific intention of expressing to the Society the concensus of the Committee regarding its obligations, its opportunities, and its objectives.

If accord and support follows this presentation—accord and support from the officers of the Division, the officers of the Society, and, most important, the rank and file of A.S.M.E. members—then, a perpetuating program (and the organization of working personnel to achieve it) can be undertaken. Only then can the Committee's output become coherent and cumulative, and, consequently, significant. Until then the Committee's work can have no pattern from year to year, and its helpfulness to the engineering profession will be by spurt-and-stall in random direction.

And the Committee considers its work important.

The Need for a Strong Furnace and Kiln Program and the Committee's Objectives

As determined by letter canvass among committeemen, and by action taken at the Committee meeting of June 20, 1944, in Pittsburgh, the following opinions are general:

1 Furnaces and kilns[1] are of primary daily interest to a greater proportion of industrial engineers than is commonly recognized. Scarcely a product can be named the modern production of which does not involve at least one significant heating operation.

2 The real roots of a better technology of design and use of furnaces and kilns lie in a fuller and wider knowledge of combustion, fluid mechanics, heat transfer, and the effects of heat upon materials, mechanical systems, and chemical processes, all within the scope of concern of the Society in general and the Heat Transfer Division in particular.

3 Comparatively meager information and data have as yet been published or otherwise made widely available, specifically to aid the designer and user of furnaces.[2] Compared to the literature, handbook data, and formal training available to the designer and user of machine tools or prime movers, the contrast is obvious.

4 No major engineering society has laid especial, concerted, and continuing emphasis upon the scientific and engineering fundamentals of design and use of fired process heating equipment in general. Committees which have functioned so far, either in the A.S.M.E. or other national engineering societies, have restricted their interest by industry (metal, oil, textile, etc.) or by heating objective (drying, melting, etc.).

Therefore, the Committee has defined as its permanent major objective, the "development of a national point of concentration for thought, data, and knowledge concerning fired process heating equipment, to the extent that the A.S.M.E. becomes able to provide much needed leadership, critical interpretation, broadcast dissemination of knowledge, and authoritative reference in matters of industrial process heating." As such an objective is won, the Society will become "kiln and furnace headquarters."

Present Thoughts on Methods of Attaining the Committee's Objectives

Obviously, the Committee's first function will be to seek out, develop, and present the most basic, helpful, and progressive engineering and scientific papers on subjects within its domain. To provide a focus of attention on timely and worth-while topics, it may frequently schedule symposiums, forums, or round-table discussions. It is thought that at least one general roundup of kiln and furnace authorities[3] might well be featured each year—ultimately to develop into an annual event of recognized importance in the field.

As more and more papers are developed through Committee effort, it is hoped that it will be possible not only to arrange sessions at the four national meetings of the Society each year but also to provide top-notch programs for those local sections which are interested. Joint sessions with other divisions of the Society and with other societies are also to be planned.

But the Committee is thinking in many other directions than the mere development of papers and symposiums. Among the thoughts being given serious consideration are:

1 Formation of a subcommittee continually to collect, digest, and organize data of "handbook" value in the field (such as calculation sheets, charts, tables, curves, etc.), these data to be prepared on standard sheets, copyrighted in the name of the Division and the Society wherever feasible, widely released for publication (item by item as developed), and sold at cost. Over a period of years the cumulative value of such sheets could be immense and possibly result in a major A.S.M.E. published handbook.

2 Formation of a subcommittee on standardization of process-heating nomenclature and symbolism, possibly co-operative with other interested bodies and the American Standards Association.

3 A planned program of papers and articles authored by individual members of the Committee but cleared by mail through the whole Committee (so that full Committee agreement exists on fact, theory, and emphasis) for presentation and publication outside the A.S.M.E. The purpose is twofold: (*a*) To utilize nationally recognized Committee members to stimulate interest in needed directions and to organize confused phases of kiln and furnace technology; and (*b*) to widen interest in and support of the Committee's work.

4 Formation of a subcommittee to follow all research (or as much thereof as possible) being conducted in the process-heating field, whether by institutions, industrial companies, groups or associations, government bureaus, or individuals. Ultimately, this subcommittee may find it worth while to recommend or perform co-ordination service, or to suggest new avenues of fruitful study and seek out means of getting it started.

5 One member has suggested that the Committee undertake surveys and studies of trends and techniques in not widely familiar fields. "The unusual high-speed kilns which have recently been introduced in the smelting industry" and "Portland cement kilns" are offered as topics on which this Committee member has already planned an approach. Such activity would involve considerable correspondence, questionnaire, and correlation of results.

6 Another member proposes a program of education of foremen and furnace operators to an understanding of the fundamentals of heat transfer as it affects practical usage, even to the extent of arranging for the production of a popularized movie on "Mr. Btu."

7 Another member suggests surveys among "students of heat transfer" and "user industries" to establish "fundamental requirements" and "directions of furnace development." This same member proposes emphasis upon the economics (installation and operation costs per unit of production) of "different methods of heat transfer for different materials, temperature levels, and temperature heads."

Obviously, the foregoing activities would involve long-term planning and reasonable financial support. At the moment they are mere suggestions, but it is hoped that specific action can be taken at a Committee meeting to be called at the time of the 1944 Annual Meeting of the Society in New York. In the meantime, comment, criticism, and new viewpoints are encouraged from all—in the Committee, in the Division, in the Society, and in the field.

Committee Membership, Organization

The present Committee roster is appended. Around the backbone of its two original and most authoritative members (Professors W. Trinks and H. C. Hottel) the Committee has now elaborated to a corps of ten.

Membership is balanced as follows: Academic and research, 3 (Hottel, Trinks, Paschkis); electric-firing specialists, 2 (Peck, Cherry); fuel-firing specialists, 2 (Segeler, Ticknor); major heat-using industry engineers, 1 (Ticknor); equipment manufacturers, 3 (Peck, Cherry, Smith); consultants, 4 (Trinks, Hottel, Segeler, Paschkis); reportorial, 3 (Olive, Wishoski, Smith); leaders in

[1] More properly "fired process heating equipment" for the oven and lehr, the open units of high-frequency induction, the new machine tools for heat-treatment, and other fueled or electrically energized media of heat transfer to work, have grown inextricably into the traditional domain of the kiln and the furnace.

[2] It is worthy of note that four of the most outstanding and widely known works so far are products of members of the Committee: the 2-volume text "Industrial Furnaces," by Prof. W. Trinks; the work of Prof. H. C. Hottel on radiant heat transfer, most familiar through Section 7 in Perry's "Chemical Engineer's Handbook;" the text "Combustion" prepared for the American Gas Association by C. George Segeler; and the cumulative contributions of the only national magazine exclusively devoted to all aspects of the fired process heating field, *Industrial Heating*, published and edited by I. Stanley Wishoski.

[3] Following the lead of, and annually improving over, the Committee's successful "Symposium of 24 Viewpoints on Recent Developments in Kiln and Furnace Design," Semi-Annual Meeting, Pittsburgh, June 19, 1944. (A summary of the discussion at this symposium was prepared by Prof. H. C. Hottel and appeared in Mechancial Engineering, vol. 66, 1944, pp. 609–610.—Editor.)

other A.S.M.E. Divisions, 1 (Olive). Such analysis shows that it would be desirable to add members from among the top heating engineers in additional major heat-using industries (possibly the steel, or oil, or ceramic industries) and from the Metals Engineering Division of the Society (Olive already representing the Process Industries Division).

The Committee considers its work important enough to warrant a membership of 20 or 25, if willing, working, capable pairs of hands beyond the 10 already enlisted can be found. But the Committee wishes its further enlistments to be voluntary from among those who see the need for a strong program in a neglected quarter of engineering and whose interest is sufficient to work (not merely concur) in that direction.

On such a basis our recruiting office is always open.

Committee on Industrial Furnaces and Kilns
A.S.M.E. HEAT TRANSFER DIVISION

HARRY W. SMITH, JR., *Chairman*, Selas Corporation of America.

PROF. W. TRINKS, *Ex officio*, Carnegie Institute of Technology.

R. M. CHERRY, Industrial Division, General Electric Company.

PROF. H. C. HOTTEL, Chemical Engineering, Massachusetts Institute of Technology.

THEODORE R. OLIVE, Associate Editor, *Chemical & Metallurgical Engineering*.

DR. VICTOR PASCHKIS, Research Associate, Columbia University.

C. E. PECK, Heating Section Engineer, Westinghouse Electric & Mfg. Co.

C. GEORGE SEGELER, Engineer of Utilities, American Gas Association.

W. A. TICKNOR, Furnace Engineer, Corning Glass Works.

I. STANLEY WISHOSKI, Publisher, *Industrial Heating*.

International Federation of Engineering Institutions Organized

NOTICE has been received concerning a proposed International Federation of Engineering Institutions. At a meeting held on June 17, 1944, it was decided to proceed with the scheme and a committee consisting of the following was set up:

Dr. H. W. Dickinson, Great Britain, *chairman;* Lieut. Colonel A. Antoine, France; A. Bertrand, France; J. J. Ducenne, Belgium; J. G. Ernst, Czechoslovakia; Major P. Kronacker, Belgium; Felix Meyers, Luxembourg; Frank Parfett, Great Britain; L. Pijanowski, Poland; Robert S. Nilsson, Sweden, *secretary*.

According to the announcement the Dominion Council of Professional Engineers in Canada and The Engineering Institute of Canada have indicated their intentions of appointing representatives.

Address communications to C.O.I.F.E., 42 Warrington Crescent, London, W. 9.

Aims and Objects

The Federation has announced the following aims and objects:

1 To inculcate a spirit of fellowship, unity, responsibility, and public spirit among engineers in all lands.

2 To combine the national institutions and associations of engineers and technicians of all countries and the related specialized international associations already in existence:

(*a*) To organize and develop on an international basis the relations between these different associations and their members, as well as to promote the representation of engineers and technicians on the various national and international associations and international bodies in which technical matters play a role.

(*b*) To study and work out in common those problems which affect the role, development, and spreading of technical knowledge throughout the world, with special encouragement for research work connected with engineering.

(*c*) To study and deal with all questions relating to the functions of engineers and technicians throughout the world, including those which concern the duties and status of engineers from professional and social standpoints.

(*d*) To foster relations with the competent authorities and to facilitate exchange of engineers and specialists.

Questions of a political or religious nature and intervention in racial disputes will not be dealt with.

Program

It is the intention of the Federation to carry out its aims by

(*a*) Promoting international congresses to which all engineers shall be invited.

(*b*) Holding annual meetings of representatives and affiliated associations.

(*c*) Setting up committees to study questions of an international and professional nature.

(*d*) Organizing lectures and exhibitions to demonstrate new methods and instruments.

(*e*) Reporting annually the proceedings of meetings held, and the administrative and technical work of the Federation.

(*f*) Making available professional literature among members.

(*g*) Issuing at intervals a bulletin or journal to convey to members information as to the activities of the Federation.

(*h*) Doing all such other acts that shall promote the aforementioned aims.

Joint A.I.E.E.-A.S.M.E. Committee on a Recommended Specification for Prime Mover Speed Governing

THE Joint A.I.E.E.-A.S.M.E. Committee was organized in 1941 for the purpose of preparing a recommended specification for the speed-governing of prime movers intended to drive electric generators, following approval by action of the A.I.E.E. Board of Directors on January 30, 1941, and of the A.S.M.E. Council on June 15, 1941.

The personnel of the Joint Committee, acting under the sponsorship of the A.S.M.E. Power Division, was nominated jointly by the chairmen of the A.I.E.E. Committee on Power Generation and the A.S.M.E. Standing Committee on Power Test Codes.

After two years of fundamental studies necessary for the preparation of a specification, a tentative draft was presented at the A.I.E.E. National Technical Meeting in June, 1943, and at the A.S.M.E. Annual Meeting in December, 1943. On the basis of comments submitted, a revised specification was prepared and approved by the A.I.E.E. Standards Committee for publication on a trial basis for one year, thus affording interested persons additional opportunity for critical examination of this specification and for the submission of comments during the trial period.

Copies of the specification (A.I.E.E. No. 600—July, 1944) are available and may be had on application to the American Institute of Electrical Engineers, 29 West 39th St., New York, N. Y.

The scope of the specification has been temporarily limited to steam turbines intended to drive electric generators rated not less than 10,000 kw. Plans are currently under way for extending the scope of the specification to include the speed-governing of all types of prime movers intended to drive electric generators and progress reports will be made from time to time in order that the Joint Committee may have the benefit of comments from interested persons.

It should be recognized that interest in the problem of speed governing varies depending upon the circumstances involved, and it was therefore necessary to prepare a recommended specification that effects a compromise between divergent interests and viewpoints. To this end the contents of this specification have been limited to those fundamental functional and performance requirements that are generally agreed to be essential and necessary for the satisfactory and acceptable speed-governing of prime movers. In particular instances it may be desirable to modify the provisions of the specification in respect either to performance or equipment, and it is not intended to preclude such modification if mutually agreeable to the purchaser and manufacturer.

A.S.M.E. Members Visit Aberdeen Proving Ground

ON October 4 about 25 members of the A.S.M.E. from Washington, Philadelphia, and the New York area visited the Aberdeen Proving Ground with Col. James L. Walsh, chairman of the A.S.M.E. War Production Committee, to attend equipment demonstration and inspection of research activities.

The first feature was a parade of vehicles, consisting of everything from bicycles and motorcycles to tractors towing 120-mm guns and 155-mm-gun motor carriages. Amphibians and all other types of motorized equipment were included and each was explained by Colonel Eddy as it passed the visitors.

The second feature was a display of small arms, grenades, grenade launchers, and bazookas. Members of the party were given the opportunity of firing some of the light arms. Many types of enemy machine guns, antiaircraft guns, and tanks were also inspected.

Correction

IN announcing appointments to A.S.M.E. committees in the October issue an unfortunate omission confused the personnel of two committees. The correct appointments are:

Power Test Codes, No. 17, on Internal-Combustion Engines, W. W. Schettler. Special Research Committee on Internal-Combustion Engines, Lee Schneitter, chairman, W. L. H. Doyle, M. A. Elliott, C. W. Good, and W. F. Joachim.

Among the Local Sections

Edward S. Bunn Talks Before Baltimore Section on Magnesium Alloys

AT the first meeting to be held this season by the Baltimore Section of the A.S.M.E., on September 25, Edward S. Bunn, the speaker of the evening, gave an excellent talk on "Wrought Magnesium Alloys, Their Fabrication and Uses." Mr. Bunn, who is metallurgical manager of the magnesium aluminum division of the Revere Copper and Brass Company, is co-author of the book "Copper and Copper-Base Alloys." He is a member of the A.S.M.E. as well as several other engineering societies and is a project member of the War Metallurgy Committee. In part Mr. Bunn spoke as follows.

Weight Savings Increase Magnesium Demands

The necessity for effecting weight savings in equipment, either for transporting or to be transported, during the present time, has increased tremendously the demand for magnesium alloys in all of their commercial forms. Magnesium alloys readily with manganese, aluminum, and zinc to form a series of high-strength, lightweight, engineering alloys, which have found many applications in the form of sand castings, forgings, and fabricated parts in aircraft and ordnance.

Metallurgical advances have improved the corrosion resistance of the magnesium alloys so that they are definitely superior to mild steel and almost as good as the aluminum alloys. Advances in fabrication methods have made it possible to produce high quality and uniform mechanical properties on a commercial basis. Fusion-welding methods for joining magnesium alloys have been developed to a high degree of perfection, so that in this respect they do not have to take a back seat to other metals and alloys.

Methods Perfected

Methods for the deep drawing and forming of magnesium alloys have been perfected to the point where, under the proper conditions, it is possible to effect a heavier reduction in one operation than with any of the other common industrial metals.

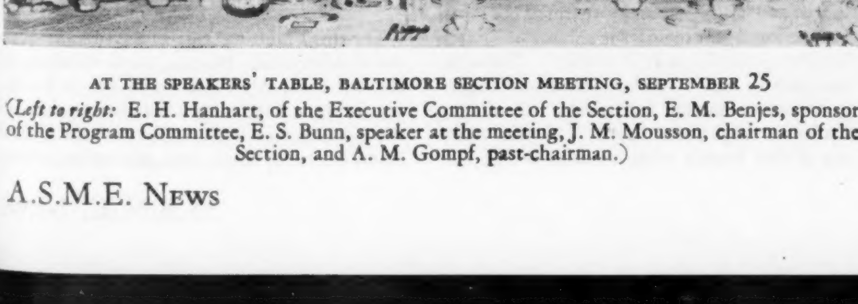
These developments in the metallurgy and fabrication of wrought magnesium alloys, coupled with the war demands, have increased the production of wrought magnesium alloys from a few thousand pounds per month in 1939 to over a million pounds per month in 1944.

1944-1945 Program Released by Central Illinois

An advance release concerning contemplated 1944-1945 activities was issued by the Central Illinois Section on September 7, as follows: October 12, "Postwar Education in Three Dimensions," a lecture by Arthur Shuman, president, Polarizing Instrument Company, New York, N. Y.; November 9, "The Engineering High Lights of the Normandie Salvage," an illustrated lecture by A. C. W. Siecke, consulting engineer, Merritt-Chapman & Scott, New York, N. Y.; December 14, "Mobile Steam Power Plants," an illustrated lecture by F. G. Ely, Babcock & Wilcox Company, New York, N. Y.; January 11, "Designs for Living," a summary of a comprehensive housing survey, by D. M. Hobart, manager of research, Curtis Publishing Company, Philadelphia, Pa.; February 8, "The Supersonic Reflectoscope," an illustrated lecture by Prof. F. A. Firestone, University of Michigan; March 8, "Helicopters," to be presented by an authority in the field; April 12, "President's Night," by the president of the A.S.M.E., guest speaker, and May 11, "Engine Turbo-Supercharger," speaker to be supplied by the General Electric Company, Schenectady, N. Y.

"House Heating" and "Heat Pump Principles" Are Subjects at East Tennessee

"A Study of the Use of Electricity in House Heating," by Buford H. Martin of the TVA, and "Principles of the Heat Pump," by Prof. Mack Tucker of the University of Tennessee, were subjects discussed at a joint dinner meeting of the East Tennessee Section and members of the A.I.E.E., on September 26, in the S & W Cafeteria, Knoxville, Tenn.



AT THE SPEAKERS' TABLE, BALTIMORE SECTION MEETING, SEPTEMBER 25
(*Left to right:* E. H. Hanhart, of the Executive Committee of the Section, E. M. Benjes, sponsor of the Program Committee, E. S. Bunn, speaker at the meeting, J. M. Mousson, chairman of the Section, and A. M. Gompf, past-chairman.)

Fort Wayne Section Learns of Postwar House

An interesting illustrated lecture on "The Postwar House," was given by George Fred Keck, at the September 21 meeting of the Fort Wayne Section. Mr. Keck showed numerous Kodachrome slides of the solar-type postwar house which he has designed and built, including both interior and exterior views.

The Sugar Industry Discussed at Honolulu Section

On August 11, the Honolulu Section met at La Hula Rhumba, Honolulu 54, Hawaii, to hear Walter E. Smith speak on the subject of "The Impact of War on the Hawaiian Sugar Industry." Mr. Smith told members that the production of sugar has dropped only 7 per cent since the beginning of the war, although labor has been cut almost in half. The loss of labor, however, has been overcome by the use of labor-saving machinery. Mr. Smith also discussed the living conditions of the plantation employees, which he said have greatly improved in the last few years. At the August 18 luncheon meeting of this Branch, Roy King, sculptor of the New York World's Fair, 1939, spoke on, "War Memorials."

Basic Story of Steel Told at Mid-Continent Section

The basic story of steel from the time raw ore, coal, and limestone leave the ground to the finished product in its many forms was told by A. L. Kay, manager of the Alloy Bureau of the Metallurgical Division, Carnegie-Illinois Steel Company, to members of the Mid-Continent Section when they met at the Mayo Hotel, Tulsa, Okla., on August 24. Mr. Kay high-spotted his comments by the use of a film and lectured on the characteristics and uses of the present alloys, as well as the prospects for these metals in the postwar period.

Management Technique Outlined at San Francisco Section

A successful luncheon meeting was held in the Green Room of the St. Francis Hotel, San Francisco, Calif., on September 13, under the joint sponsorship of the San Francisco Section and members of the Society for the Advancement of Management. The guest speaker was Dr. Lillian M. Gilbreth, who discussed "New Operating Technique in Management," Dr. Gilbreth spoke in general terms on new problems facing management due to the war, and touched briefly on the need for industrial medicine which became apparent during this period of mass production. In some organizations, Dr. Gilbreth said, biomechanics laboratories have been set up and all the therapies are being employed to reduce absenteeism. A need for counselors also has been brought about by the employment of women, she stated, and such counselors are being added to the staffs of some of the large industrial organizations.

Production Film Features Schenectady Meeting

Chris Steenstrup of the General Electric Company, Schenectady, N. Y., presented a film on "Improving Production Through Quality Control," at the September 28 meeting of the Schenectady Section, in the Old Chapel, Union College, Schenectady, N. Y. The film was shown in two sections—the first featured Mr. Steenstrup's own story of how production improves through the use of high-grade materials, ultimately lowering cost, while the second section, under the title "After Victory," presented his philosophies on postwar problems.

Industrial Engineering Bibliography Available

THE College of Engineering, University of Iowa, Iowa City, Iowa, has recently published a "Bibliography of Industrial Engineering and Management Literature to Jan. 1, 1943," by Ralph M. Barnes, member A.S.M.E., professor of industrial engineering and director of personnel, University of Iowa, and Norma A. Englert, librarian of the engineering library, University of Iowa.

The Bibliography, which contains 2539 references, was prepared not only for the use of students working in the industrial-engineering laboratory but also for persons from industry attending the management course at the university.

Copies of the Bibliography may be purchased from the College of Engineering of the University of Iowa.

Neil P. Bailey to Head M. E. Department at Rensselaer

NEIL P. BAILEY, member A.S.M.E., since 1922 with the General Electric Company, and for six years head of the department of mechanical engineering at Rutgers University, has been appointed head of the department of mechanical engineering at Rensselaer Polytechnic Institute. He will succeed Prof. Edwin A. Fessenden, member A.S.M.E. who will retire Oct. 31, 1944.

A.S.M.E. Calendar

of Coming Meetings

November 27–December 1, 1944
A.S.M.E. Annual Meeting
New York, N. Y.

April, 1945
A.S.M.E. Spring Meeting
Boston, Mass.

June, 1945
A.S.M.E. Semi-Annual Meeting
Chicago, Ill.

Fuel and Lubrication Problems in Aviation at Meeting of Junior Metropolitan Group, Nov. 21

THE topic of discussion at the November meeting of the Junior Group of the A.S.M.E. Metropolitan Section will be "Fuel and Lubrication Problems of the Aviation Industry" as presented by Allen E. Smith, technical manager of the Aviation Department of the Socony-Vacuum Oil Company, Inc.

Tremendous Interest in Both Problems

Tremendous interest displayed by members in matters affecting the aviation and petroleum industries prompted the scheduling of this subject. The popular appeal of these two groups' activities particularly emphasized by their role in prosecuting America's war effort should command a large attendance at the Juniors' pre-convention meeting. Through misinterpretation or misunderstanding of the facts many people have developed mistaken notions regarding the true significance of such common terms as "octane number" or whether general-purpose or specialized lubricants are employed for the varied flying conditions of the several war theaters.

In so far as possible Mr. Smith will present a general picture of the broad field of fuels, oils, and greases, outlining briefly the characteristics of the several different types and kinds of each. Where censorship permits, mention will also be made of the various problems which the oil companies in conjunction with the aircraft manufacturers and the Services were required to solve.

Speaker Well Qualified

The speaker, a graduate M.E. from Lehigh University, has a varied background of business experience in machine design, plant management, sales, and engine-lubrication research. While engaged with the general laboratories of Socony-Vacuum, Mr. Smith's work was concerned with the development of internal-combustion-engine fuels and lubricants. He was in charge of his company's engine-laboratory activities in the development of engine tests and research in connection with evaluation of fuels and lubricants. As technical manager of the aviation department, Mr. Smith has closely followed the application of all petroleum products as related to aircraft and aircraft engines. This has necessitated close contact with the development of new products to meet new needs in the aviation industry and keeping in close contact with the Armed Services as to their requirements, resulting in the attainment of a broad over-all picture relative to petroleum products and their use in aircraft.

Question-and-Answer Period

A question-and-answer period, as is the usual custom, will follow the talk. The meeting will be in charge of Joseph M. Sexton of The M. W. Kellogg Company.

With the Student Branches

Dam Projects Discussed at Colorado Branch

UNIVERSITY OF COLORADO BRANCH met on September 13, to hear F. C. Allen of the Bureau of Reclamation briefly discuss the various dam projects handled by the Bureau. Mr. Allen also showed two interesting films—a motion picture depicting the construction of Boulder Dam, and a silent color film describing the Skagit projects undertaken in the State of Washington. An informal discussion period concluded the lecture.

A motion picture entitled, "Surface Condensers," featured the August 18 meeting of DUKE BRANCH. Tentative plans of a contemplated trip to the Sanford aircraft-parts plant also were discussed.

A summary of the term's work of the UNIVERSITY OF ILLINOIS BRANCH recently was submitted by the Branch's secretary, D. O. Wilson. At the February 23 meeting, Professor Leutwiler spoke on the subject of "Opportunities for Mechanical Engineers." On March 8, members viewed two motion pictures entitled, "PT-19 Trainer" and "Flying Fortress." Professor Walker, a well-known metallurgist and ballistics expert, featured the April 19 meeting, speaking on the subject of "Artillery Projectiles Used in This War." The members met on May 17 to hear Professor Trigger give an interesting lecture on "Hardening Cycles for High-Speed Steels." A joint meeting of this Branch with members of the A.I.E.E. was held on August 22, at which Lieutenant Clark, officer in charge of the Signal School, discussed the duties of mechanical and electrical engineers at sea. Members of this Branch met jointly on September 14 with members of the A.I.E.E. to hear H. C. Rountree, supervisor of engineering extension, speak on the subject of "The Future of Engineering Grads in Industry."

Election of representatives to the Engineering Council was held at the August 2 meeting of IOWA BRANCH, with Henry Haegg appointed senior representative and Bud Rawson, junior representative. Prior to the election, President Hunter explained the many opportunities open to student members by membership in the A.S.M.E.

LAFAYETTE BRANCH met on September 13 for the main purpose of electing officers for the coming year. A new chairman, vice-chairman, secretary, and treasurer were appointed, although at the time of going to press the names of the officers were not available for publication.

"Electrical Propulsion in the Navy" Features Maryland Meeting

The third joint meeting of the summer quarter of MARYLAND BRANCH, with members of the A.I.E.E., A.I.CH.E., and the A.S.C.E., was held on August 29. The guest speaker of the evening was William Fifer of the United States Bureau of Ships, who gave an interesting

illustrated lecture on "Electrical Propulsion in the Navy."

Two motion pictures, lent through the courtesy of *Modern Plastics*, and the New Jersey Zinc Company, New York, N. Y., featured the September 1 meeting of Minnesota Branch. The one film presented a nontechnical account of plastics, the manufacture and usages, while the second film outlined the procedure and materials used in manufacturing die castings.

Professor Cortez of the English department of New Hampshire Branch at the beginning of the 1944 summer sessions spoke on the topic of "How to Make a Speech," and each meeting thereafter was devoted primarily to presentation of student papers. In addition to the three student papers read at the August 21 meeting of this Branch, new officers for the 1944-1945 term were elected. They are: John Baker, chairman, and Robert Wakeman, secretary-treasurer.

Wind Turbines Explained to M.I.T. Branch

Announcement of a Student-Prize Speaking Contest was made at the August 17 meeting of Massachusetts Tech Branch, with all members of the Student Branch eligible. Prof. John B. Wilbur, chief project engineer for the S. Morgan Smith Company, York, Pa., highspotted the evening with an illustrated lecture on "Power From Winds." He outlined in detail the Smith-Putnam wind-turbine project on Grandpa's Knob in the Green Mountains of Vermont. Other noteworthy events recently enjoyed by members of this Branch included two field trips—one to the Croft brewery and one to the plant of the New England Confectionery Company. Methods of production, industrial machinery, and operative methods were studied and discussed on these trips.

Pennsylvania Branch Elects New Officers

Officers elected at a recent meeting of Pennsylvania Branch are as follows: President, Miss Althea June Schaffer; vice-president, Walter Aptulsky, and secretary-treasurer, W. Lee Fairchild. At the September 13 meeting of this Branch, members enjoyed three interesting motion pictures entitled, "West Lynn;" "It's Up to Us," and "Sand and Flame."

One of the most successful beach parties ever held by members of the University of Southern California Branch took place on August 19 at Castle Rock Beach, located three miles north of Santa Monica Beach. The party was well attended by membersand theirgirlfriends, together with several guests of the A.S.C.E. On August 28, members of this Branch met to make final preparations for a field trip to the plant of the Sterling Electric Motor Company. This Branch met again on September 8 to view two motion pictures. One picture illustrated the Panama Canal Locks in operation, while the other depicted the essentials of television.

New Officers at Swarthmore

On August 17, Swarthmore Branch held its first meeting of the semester to elect new officers as follows: Mark Moore, honorary chairman; Robert Rath, chairman; Daniel Wingerd, vice-chairman, and John Kelly, secretary-treasurer. Chairman Rath then appointed a membership committee, a program committee, and a temporary committee to investigate the by-laws.

Tufts Branch Inspects Mystic Station

On September 26 eighty members of the Tufts Branch made an inspection tour of the New Mystic Station of the Boston Edison Company. The trip started at the cooling-water intake house. There they were separated into small groups who went in turn to the top of the station and worked down through the plant to the turbine room, and finally to the switch room.

"Naval Engineering and Its Aspects," was the topic chosen by Lieut. Comdr. S. B. Smith, guest speaker at the August 24 meeting of Tufts Branch. Commander Smith described the various departments maintained aboard ship, together with the smooth functioning of each. Members of this Branch held an all-day beach party on August 26, at Lynn Beach, Lynn, Mass. Twenty-four members and their girl friends attended the party.

Members of the University of Virginia Branch, accompanied by H. C. Hesse, associate professor of engineering drawing, during the week ending June 10 devoted a day each inspecting the Singer Sewing Machine plant at Elizabeth, N. J., and the Brooklyn Navy Yard, N. Y. This Branch met on August 10 to elect new officers as follows: H. R. Housell, president; W. T. Starnes, vice-president; F. G. Hilbish, secretary; H. K. Wooster, treasurer; D. H. Sprecker, chairman of the Program Committee, and A. Cagliostro, chairman of the Membership Committee.

War Films Feature Recent Meetings at Villanova

At the August 18 meeting of Villanova Branch, members viewed an exceedingly interesting motion picture entitled, "B-17, Fortress of the Sky." This Branch met again on August 22, in the Ampitheater of Mendel Hall, to enjoy another motion picture, entitled "PBY Record Breakers," which outlined the construction and performance of the Consolidated "Catalina" patrol bombers. Prof. J. C. Greyson of the mechanical-engineering department, and formerly associated with the Naval Aircraft Factory, Philadelphia Navy Yard, then discussed some of the techniques which were used in the production of the planes at the Naval Aircraft Factory.

"Wheels Across India"

"Wheels Across India," was a motion picture enjoyed by members of the Virginia Polytechnic Branch on August 28. After the film was shown, members elected O. J. Parsons, treasurer, to succeed G. A. Main, and then heard two student papers read—one by E. R. Epstein, who described the construction and peration of gas turbines, and one by J. B. Jones, who outlined wall-fired oil furnaces.

Student members delivered ten-minute talks each at three meetings of Yale Branch as follows: August 22, W. E. Chapman, "The Philadelphia;" M. Whiting, "T Formation;" S. Lampert, "The Navy;" and R. H. Kalbach, "Aerial Gunnery." August 29, E. G. Mudarri, "Jay Gould;" H. E. Zimmerman, 'The Malaria Menace;" A. R. Ford, "Codes and Ciphers;" and C. J. McCarthy, "Problems and Grievances of a Boomtown." September 12, W. N. Plamondon, Jr., "Josiah Willard Gibbs;" T. F. Keating, "Progressive Education;" A. S. Linzell, "B29—Superfortress;" and M. A. Schuchat, "The Human Element in Warfare."

A.S.M.E. Local Sections

Coming Meetings

Atlanta. November 20. Atlanta Athletic Club at 7:45 p.m. Subject: "Stress Concentration and Fatigue Failures," by Dr. Stephen P. Timoshenko, professor of theoretical and applied mechanics, Stanford University, Calif.

Baltimore. November 27. Engineers' Club, 6 West Fayette St., Baltimore, Md. Subject: "Power Plants for Merchant Vessels," by A. S. Thaeler.

Birmingham. November 16. Hotel Tutwiler at 8:00 p.m. Subject: "Stress Concentration and Fatigue Failures," by Dr. Stephen P. Timoshenko.

Central Illinois. November 9. Subject: "The Engineering High Lights of the *Normandie* Salvage," by A. C. W. Siecke, consulting engineer, Merritt-Chapman and Scott Corp., New York, N. Y.

Charlotte. November 22. Charlotte Hotel at 6:30 p.m. Subject: "Stress Concentration and Fatigue Failures," by Dr. Stephen P. Timoshenko.

Greenville. November 17. This meeting will be held at Asheville, N. C. Subject: "Stress Concentration and Fatigue Failures," by Dr. Stephen P. Timoshenko.

Knoxville. November 21. Ferris Hall, University of Tennessee at 8:00 p.m. Subject: "Stress Concentration and Fatigue Failures," by Dr. Stephen P. Timoshenko.

Memphis. November 15. Hotel Peabody at 8:00 p.m. Subject: "Stress Concentration and Fatigue Failures," by Dr. Stephen P. Timoshenko.

New Haven. November 8. Mason Laboratory, Hillhouse Ave. at 8:00 p.m. Subject: "Refractories for Metal Melting," by Messrs. Donald F. Sawtelle, metallurgist, Malleable Iron Fittings Co., and Seaver H. Booth, foreman, The American Brass Co.

New Orleans. November 13. Subject: "Stress Concentration and Fatigue Failures," by Dr. Stephen P. Timoshenko.

Raleigh. November 23. Subject: "Stress Concentration and Fatigue Failures," by Dr. Stephen P. Timoshenko.

South Texas. November 10. Sam Houston Room, Rice Hotel at 8:00 p.m. Subject: "Stress Concentration and Fatigue Failures," by Dr. Stephen P. Timoshenko.

Toledo. November 16. Subject: "Hydraulic Transmissions for Motor Vehicles," by A. H. Deimel, engineer of Spicer Manufacturing Corporation, Toledo, Ohio.

Tri-Cities. November 10. Subject: "The Engineering High Lights of the *Normandie* Salvage," by A. C. W. Siecke.

Virginia. November 24. Richmond, Va., at 8:00 p.m. Subject: "Stress Concentration and Fatigue Failures," by Dr. Stephen P. Timoshenko.

Basic Standards for Glued Laminated Lumber Development

THE Central Committee on Lumber Standards has undertaken to establish the necessary machinery for and to supervise the development of basic standards for glued laminated lumber products, according to an announcement of the Division of Simplified Practice of the National Bureau of Standards.

A permanent standing committee appointed by the General Conference of the Lumber Industry called by the Secretary of Commerce, the Central Committee on Lumber Standards, is representative of all groups that have an interest in lumber standards. It is the agency through which the American Lumber Standards were developed, and whose recommendations were promulgated by the Department of Commerce, through the Division of Simplified Practice of the National Bureau of Standards. Since the original publication of the American Lumber Standards as Simplified Practice Recommendation R16, in 1924, they have been kept abreast of the times by the Committee, through the procedures of the Division, the latest revision having been completed in 1939. The Committee has thus come to be regarded as the most appropriate agency for the handling of all questions having to do with basic standards in their field.

Action in Response to Request

The Central Committee's action is in response to a request made in a resolution adopted by an informal conference of lumbermen, fabricators, and glue manufacturers held in Chicago on June 3, 1943, and formally presented to the Committee by the executive committee of the National Lumber Manufacturers Association. Interest in glued laminated lumber products has grown rapidly in this country in the last decade, and an informal conference had already set up a Temporary Executive Committee and subcommittees on glues, fabrication, lumber, inspection and certification, boats, ships, land vehicles, and miscellaneous subjects.

In January, 1944, John Foley, chairman of the Central Committee on Lumber Standards, met with these committees and described the plan of the Central Committee. All the development work, he stated, would be done by and through technical committees which the Central Committee would appoint, the Central Committee assuming the responsibility for determining that adequate opportunity had been afforded those interested to consider and be heard on any proposed standard submitted to it.

The plan in general follows that used in developing the American Lumber Standards, which have come to be accepted as one of the most outstanding achievements in the history of the industry and of standardization.

Consulting Committee

Immediately subordinate to and reporting to the Central Committee will be a Consulting Committee on Laminated Lumber Standards. Its members will be representative of the various component industry operations involved, and will be sufficiently experienced to determine, prior to any conferences, whether the standards submitted to them are adequate and whether proper consideration has been given the public and private interests involved. The Consulting Committee may either refer reports back to the committees of origin or recommend them to the Central Committee for consideration.

Standards Development and Technical Committees

The drawing up of recommendations will rest with working committees to be known as Standards Development and Technical Committees. At present, eight such committees are planned as follows:

No. 1 Structural uses (framing for buildings, bridges, towers)
No. 2 Maritime uses (ships, boats, barges)
No. 3 Vehicular uses (automotive, trailers, wagons, rolling stock)
No. 4 Coverings and panels (for buildings and other structures)
No. 5 Millwork (doors, sash, trim, cabinets)
No. 6 Furniture (residential, office, store fixtures)
No. 7 Aircraft (wings, fuselage, frames)
No. 8 Remanufactured uses (lasts, toys, implements)

Each SDT Committee will be divided into subcommittees to deal with the various phases of its subject. The subcommittees are directed by the Central Committee to obtain the advisory services of the Forest Products Laboratory, Forest Service, U. S. Department of Agriculture, and to make their explorations and studies complete, bringing into their discussions all those whose opinions and information should be sought, whether members of the committee or not. The Chairman of each SDT Committee and its subcommittees are to correlate the data prepared by the subcommittees and define any special terms in their proposals. The four subcommittees of SDT Committee No. 1, for example, will be concerned with: (1) Lumber, (2) fabrication, (3) glues, and (4) inspection. Thomas D. Perry, who has been active in the A.S.M.E. Wood Industries Division for many years, is chairman of the Subcommittee on Glues.

Although it was deemed desirable that the organizational setup and responsibilities of the various SDT Committees be clear-cut and separate, it was recognized that there would inevitably be an overlapping of work and that some of the subcommittees might and should have identical personnel. This was particularly true in the case of the first three committees. Further, in order to utilize the considerable progress and initiative already realized the personnel of the new committees continued substantially as set up by the informal conference of June, 1943.

C. D. Dosker, of Gamble Brothers, Louisville, Kentucky, was appointed chairman, and Frank J. Hanrahan, of the National Lumber Manufacturers Association, secretary, of SDT Committees Nos. 1, 2, and 3.

The personnel of the subcommittees on Lumber, Glues, and Inspection of SDT Committees 2 and 3 is the same as that for the corresponding subcommittees of SDT Committee No. 1. Subcommittees on Fabrication for SDT Committees 2 and 3 have not yet been named.

Purdue Receives Ordnance Distinguished-Service Award

THE Ordnance Distinguished-Service Award was presented to Purdue University at ceremonies conducted at the University on Sept. 14, 1944. The certificate of the award, "in recognition of outstanding and meritorious scientific and educational contributions," was presented by Brigadier General A. B. Quinton, Jr., U. S. Army, and was received by President Edward C. Elliott. Dean A. A. Potter, past-president A.S.M.E. delivered a brief address in accepting the award and Prof. G. A. Hawkins, member A.S.M.E., spoke briefly.

It is understood that the award was made in recognition of research work carried on in the school of mechanical and aeronautical engineering under the immediate direction of Professor Hawkins, member of the A.S.M.E. Standing Committee on Research.

Co-Operative Program of Douglas and U. of Texas

M. V. BARTON, professor of aeronautical engineering at The University of Texas, and member A.S.M.E., has been on leave of absence, to participate in a co-operative program with the Douglas Aircraft Company, of Santa Monica, Calif. Dr. Barton was engaged in productive assignments in the engineering department, particularly in structures and in vibration and flutter.

This co-operative program was developed by C. T. Reid, manpower assistant to A. E. Raymond, vice-president in charge of engineering for Douglas, and M. J. Thompson, chairman of the department of aeronautical engineering at the University of Texas. The program represents one of the pioneering efforts to provide for closer relationships between industry and education, from which engineering instructors and industrial personnel may obtain a better understanding of their mutual problems.

Structural Failures in Welded Ship Construction

THE factors causing failure in welded ship construction and some suggested means for their control are presented in a report, "Structural Failures in Welded Ship Construction," published by the American Welding Society.

This report is an extension of the principles set forth in the previously published report, "Thermal Stresses and Shrinkage in Welded Ship Construction."

The new report is being presented at this time to assist the shipbuilding industry in its welding problems until extended studies now being carried on are completed and fully reported.

Copies of the report are available in the form of a 6 × 9-in. bulletin and may be purchased from the American Welding Society, 33 West 39th Street, New York 18, N. Y.

Engineering Societies Personnel Service, Inc.

These items are from information furnished by the Engineering Societies Personnel Service, Inc., which is under the joint management of the national societies of Civil, Electrical, Mechanical, and Mining and Metallurgical Engineers. This Service is available to members and is operated on a co-operative, nonprofit basis. In applying for positions advertised by the Service, the applicant agrees, if actually placed in a position through the Service as a result of an advertisement, to pay a placement fee in accordance with the rates as listed by the Service. These rates have been established in order to maintain an efficient, nonprofit, personnel service and are available upon request. This also applies to registrants whose notices are placed in these columns. All replies should be addressed to the key numbers indicated and mailed to the New York office. When making application for a position include six cents in stamps for forwarding application to the employer and for returning when necessary. A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription of $3 per quarter or $10 per annum, payable in advance.

New York	Boston, Mass.	Chicago	Detroit	San Francisco
8 West 40th St.	4 Park St.	211 West Wacker Drive	109 Farmsworth Ave.	57 Post Street

MEN AVAILABLE[1]

MECHANICAL ENGINEER. Fifteen years' experience with all types of welding equipment for nonferrous and ferrous metals. Control of process, tooling, development, and specification of equipment for economy of operation and maintenance. Wishes to contact private industry with good reconversion prospects. Any location considered. Me-871.

MECHANICAL ENGINEER. Proved originality. Broad experience in steam power-plant design, industrial-plant design, mechanical development, lubrication, chemical equipment, practical machine limits, and material selection. Organization ability and executive experience. Me-872.

MECHANICAL ENGINEER. Wants position as manager or chief engineer. Technical graduate, registered professional, twenty-five years' experience in development, methods, design, construction of precision and industrial equipment. Plant layout and buildings. Me-873.

MECHANICAL ENGINEER, member Tau Beta Pi, desires responsible position. Eight years' heat-engineering experience in power-plant and process design and betterment work. Capable of executive position. Me-874-1865-Chicago.

POSITIONS AVAILABLE

RESEARCH AND DEVELOPMENT ENGINEER, about 40, capable of setting up research and development department for manufacturer of various metal products such as springs, eyelets, stampings, screw-machine products, small assemblies, etc. Salary open. Connecticut. W-4283.

INDUSTRIAL ENGINEER, graduate or equivalent, with industrial background covering all phases of industrial work to head department involving product design, production planning and control, processing, machine, tool and die design, time study, plant layout, etc. Apply by letter giving complete details of education, age, past experience, and salaries earned. Michigan. W-4295-CD.

SALES ENGINEERS, under 30, for manufacturer of wire rope. Should have basic engineering training but need not be graduates. Permanent, postwar opportunities. Salary, plus car and expenses. Headquarters, New York and Missouri. W-4311-C.

PLANT SUPERINTENDENT, preferably with engineering background. Must have had actual gray-iron-foundry experience and a number of years' experience in plant management. $6000–$8500 a year. Ohio. W-4318-D.

TIME STUDY ENGINEER who has also had experience in field of incentive methods of pay. Company manufactures enameled iron plumbing fixtures. Middle West. W-4319-D.

MECHANICAL ENGINEER, graduate preferred, capable of directing drafting room and with experience in design of small mechanical-electrical parts for research and development company only. Company develops new devices and models. Postwar opportunity. $6500–$7020 a year. New York metropolitan area. W-4330.

MECHANICAL ENGINEER, not over 45, competent to design and lay out power plants for China. Should be willing to accept employment under contract to establish power-plant engineering department in China after the war. Salary open. Present location, New York, N. Y. W-4332.

DESIGNER, under 45, who has had experience on both freight and passenger cars, for railroad-car manufacturing plant in China. Applicant must be prepared to accept position under contract and proceed to China after war. Present location, New York, N. Y. W-4338.

INDUSTRIAL ENGINEER for methods, cost, and time-study work. Should have experience in small-parts assembly, such as camera or instrument work. $6000–$7200 year. New York State. W-4342.

SALES TRAINING INSTRUCTOR. Require man who has had experience and demonstrated success in training of salesmen, particularly for merchandisable products. Experience should preferably have been in field of household refrigeration, radios, and general electrical-appliance field. $7000–$8000 year. New York State. W-4354.

PRODUCTION ENGINEER with mechanical and electrical experience on light automatic machinery to supervise tooling, layout, and production of automatic assembly machine. $7000 year. Ohio. W-4367-D.

WORKS MANAGER for large plant manufacturing heavy metal products. $12,000–$15,000 year. Middle West. W-4400.

DEVELOPMENTAL ENGINEER, mechanical, on electrical household appliances. Must have had extensive experience on design and development of mixers, toasters, heating pads, etc. Should also be capable of directing and training draftsmen on layouts, etc. $5000–$7000 year. Upper New York State. W-4442.

SERVICE ENGINEERS, to 35, mechanical, either graduates or equivalent experience in power work. Will be required to go into plants where new boiler equipment has been installed and start equipment working. Will also service old equipment. Must be familiar with boiler tests, etc. Men who have operated power plants for large companies or who have had oil-refinery power-plant experience will be considered. Must be acquainted with high-pressure boilers. Company will train men. Seventy per cent of time will be spent traveling. $3600 year, expenses. Permanent. Headquarters, New York, N. Y. W-4443.

SALESMAN. Manufacturer of small precision parts and assemblies desires man to handle sales contacts and correspondence. Should be able to discuss design of customer's product for commercial production, quality requirements, etc. Connecticut. W-4457.

WORKS MANAGER for small plant. Must be a shopman; know costs and accounting; be able to understand the problems of engineering designers and draftsmen sufficiently to direct their work. Must have demonstrated executive ability and be aggressive. Permanent. New York metropolitan area. W-4459.

JUNIOR MECHANICAL ENGINEER to assist plant engineer in supervising machine design, plant layouts, installation of equipment, etc., for company in plastics field. $3000–$5000 year. New York metropolitan area. W-4462.

PLANT SUPERINTENDENT, preferably mechanical engineer, to take over large bottling operation. Experience in this field desirable as well as experience in preventive maintenance on mechanical equipment. Must be executive. Salary open. New York, N. Y. W-4468.

CHIEF DRAFTSMAN for supervisory capacity over drafting room of company manufacturing small metal parts on production basis. $5000 a year. Northern New Jersey. W-4469.

ENGINEERS. (*a*) director of engineering, 40–45, mechanical, to direct large engineering department in design of process-industry equipment and plants for replacement of existing facilities and installations of complete new plants. A top-notch administrator with sound technical experience is desired, rather than a research individual. Must be executive type. (*b*) chief draftsman, 30–40, mechanical, to supervise large drafting department engaged in design of plants and equipment for replacement of existing facilities and installation of complete new plants. Work involves training and directing draftsmen and engineering personnel. Salaries commensurate with background. Candidates should have at least five continuous years with one manufacturing organization since 1937. East. W-4472.

DETAIL DRAFTSMAN, mechanical, for structural and mill equipment layouts. $4200 year, on 40-hour week. New York, N. Y. W-4476.

SALES MANAGER, mechanical-engineering degree or its equivalent, for sale of grinders and honing machines for industrial plants. $12,000–$15,000 year. Middle West. Interviews, New York, N. Y. W-4478-C.

[1] All men listed hold some form of A.S.M.E. membership.

Candidates for Membership and Transfer in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after November 25, 1944, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member who has either comments or objections should write to the secretary of The American Society of Mechanical Engineers immediately.

KEY TO ABBREVIATIONS

Re = Re-election; Rt = Reinstatement; Rt & T = Reinstatement and Transfer to Member.

NEW APPLICATIONS

For Member, Associate, or Junior

ADAMS, WM. E., Westbury, N. Y.
ARNOLD, RICHARD M. (LIEUT.), San Francisco, Calif.
BALLESTER, RODOLFO, Argentina, S. A.
BEANE, JOHN A., Snyder 21, N. Y.
BELL, JAS. B., London, Ont., Canada
BERRY, ETHAN A., New York, N. Y.
BLACK, LLOYD V., Tarentum, Pa.
BRADFIELD, P. E., Los Angeles, Calif.
BRODEN, E. R., York, Pa.
BROWNELL, CLIFFORD E., Atlanta, Ga.
BUFFUM, T. N. (ENSIGN), Providence, R. I.
BULK, M., Pacific Palisades, Calif.
CHANDER, M., Lahore, India
CHRISMAN, JACOB W., Indianapolis, Ind.
CHRISTMAN, M. V., Inglewood, Calif.
CIBA, JOHN LAWRENCE, Woodbury, N. J.
COLLINS, LAURENCE J., Marblehead, Mass.
DAVIS, FRANK W., Boston, Mass.
DE BRUYN, THOS. D., Oakland, Calif.
DEVELIN, WM. J., New York, N. Y.
DIGGES, H. S., White Post, Va.
EINWAECHTER, FRED H., JR., Halethorpe, Md.
FARNELL, GEORGE, Cambridge, Mass.
FEDERICI, FRANK, Bridgeport, N. J.
FOX, OSCAR M., Pittsburgh, Pa.
GARSSON, HENRY M., Batavia, Ill.
GAVELEK, WM. A., Elgin, Ill.
GILLESPIE, J. J., Bridgeport, Conn.
GOLOM, JOHN P., East Orange, N. J.
GRABOWSKI, EDW., New York, N. Y.
HANSEN, GEORGE ALBERT, Pittsburgh, Pa. (Re)
HARPER, R. G., Tulsa, Okla.
HENRY, JOHN A., Urbana, Ill. (Rt & T)
HENSLEE, HOMER E., Flushing, L. I., N. Y.
HILL, WALTER C., JR., Marietta, Ga.
HORNIDGE, RICHARD D., San Francisco, Calif.
HOWELL, ALBERT G., JR. (LIEUT.), San Francisco, Calif.
HOWELL, GLEN H., Detroit, Mich.
JANDA, RUDOLPH W., Berwyn, Ill.
JOHNSON, PAUL E., Gary, Ind.
KING, J. PAYNE, Cleveland, Ohio
KOLZINO, HEINZ H., Chicago, Ill.
KOTELEV, SERGE G., Sunnyside, N. Y.
KUTZ, HARRY R. (GENERAL), Washington, D. C.
LANE, C. W., York, Pa.
LANG, HERBERT C., E. Milton, Mass.
LAWRENCE, ANDREW, Brooklyn, N. Y.
LEE, RICHARD W., Hamilton, Ont., Canada
LOONIN, H. HOWARD, Brooklyn, N. Y.
MALLAY, PAUL D., Coatesville, Pa. (Rt & T)
MANN, JOHN J., Mamaroneck, N. Y.
MARTIN, GEO. H., JR., Chicago, Ill.
METZ, DONALD T., Temple City, Calif.
MEYER, ADOLPHE, Baden, Switzerland
MEYER, CARL W., Baltimore, Md.
MILLER, HARRY C., Devon, Pa.
MILLER, J. P., Downers Grove, Ill.
MUKHERJEA, S. R., Calcutta, India
MULLEN, JOHN J., Salt Lake City, Utah (Rt)
MYERS, GLENN A., Kansas City, Mo.
MYERS, ROBERT T. (MAJ.), Davenport, Iowa
NOVAK, HOWARD M., Flushing, L. I., N. Y.
OLSON, HAROLD T., Rochester, N. Y.
PAPPAS, JAMES N. (LIEUT.), Brooklyn, N. Y.
PETERSON, W. JEROME, Fair Lawn, N. J.
PICCARDO, J. E., Oakland, Calif.
PINCHES, CONRAD H., 3RD, Rye, N. Y.
RANINEN, ARNOLD B., Havre de Grace, Md.
RICHARDS, JOHN Y., JR., Chicago, Ill.
ROBINSON, JAMES M. (ENSIGN), Hornell, N. Y.
ROSS, GILBERT I. (COL.), Rye, N. Y.
SAMUELS, SIDNEY, New York, N. Y.
SCHECK, FRED W., Chicago, Ill.
SCHETTLER, W. W., Beloit, Wis.
SCOTTRON, VICTOR E., Brooklyn, N. Y.
SEID, ROBERT B., New York, N. Y.
SHINE, ROBERT H. (LIEUT.), Birmingham, Ala.
SHOUDY, PAUL A., Seattle, Wash.
SIBLER, CHARLES J., New York, N. Y. (Rt)
SICHEL, M. L., Richmond Hill, L. I., N. Y.
SIMPSON, JAMES H., Haledon, N. J.
SMITH, RAY M., Chicago, Ill.
SOKOL, THEO. J., Cleveland, Ohio
SPALDING, L. P., Inglewood, Calif.
STOKES, CHAS. W., Sulphur, La.
SURVEYER, ARTHUR, Montreal, Que., Canada
SUSSMAN, WM., East Orange, N. J.
TALLEY, SAML. K., Berkeley, Calif.
TOWNE, MILES A., Park Ridge, Ill.
VAILL, JOHN L., Middlebury, Conn.
VICKERS, HARRY F., Detroit, Mich.
WENNER, JAMES J. (LIEUT.), Cincinnati, Ohio
WESELIK, L. J., Chicago, Ill.
WHITE, THOMAS L., Youngstown, Ohio
WILLIAMSON, WM. R., Chicago, Ill. (Rt)

CHANGE OF GRADING

Transfers to Member

ANDERSON, ROBT. C., Dundalk, Md.
ASHLEY, HENRY C., Watertown, Conn.
BEEDE, ARNOLD H., Stamford, Conn.
BROWN, WALTER H., JR., Cranston, R. I.
BRUNOT, ALBERT W., East Lynn, Mass.
BUCK, NELSON L., Rockaway, N. J.
CHAPMAN, ROBT. G., Burlington, Vt.
CHASE, L. ALVIN, Pittsburgh, Pa.
CROCKER, JOHN W., Jeannette, Pa.
D'ARCEY, ALFRED C., Brooklyn, N. Y.
DAWSON, PERCY B., JR., Berkeley, Calif.
DUNNINGTON, WM., Richland, Wash.
EVERETT, WM. S. (LIEUT.), Albany, Calif.
HATCH, GORDON H., Naugatuck, Conn.
HERVEY, EUGENE, Cleveland, Ohio
MCALPIN, WM., JR., Atlanta, Ga.
MILLS, BLAKE D., JR. (LIEUT.), Washington, D. C.
MORRIS, J. K., South Gate, Calif.
MYLROIE, JOHN E., Seattle, Wash.
NEWCOMB, WALLACE K., Painted Post, N. Y.
NORDT, PAUL W., JR., Concord, Mass.
PIERCE, MARION C., Cuyahoga Falls, Ohio
RANSOM, JAS. F., Denver, Colo.
REEVE, KENNETH A., Bound Brook, N. J.
ROWAN, ROBT. B., Portland, Oregon
SARACINO, FRANK E., Chicago, Ill.
SCHWARTZ, DANIEL M., Pittsburgh, Pa.
SHALLENBERGER, WM. H., Los Angeles, Calif.
SILLS, T. O., Concord, N. C.
SMITH, GERARD L., York, Pa.
SNYDER, SETH M., JR. (MAJOR), Baltimore, Md.
SOLOV, ABRAHAM, Flushing, L. I., N. Y.
VAKSDAL, STEINAR, Buffalo, N. Y.
WILHOIT, L. M., Dallas, Texas
WORTH, EUGENE B., Louisville, Ky.
ZEITLIN, ELI A., San Diego, Calif.

Transfer to Fellow

POWELL, SHEPPARD T., Baltimore, Md.

A.S.M.E. Transactions for October, 1944

THE October, 1944, issue of the Transactions of the A.S.M.E. contains:

An Introduction to Aircraft Hydraulic Systems, by Howard Field, Jr.

Controversy Over the Choice of a Medium for Aircraft Power Transmission, by R. L. Hayman

The Evolution of the Hydraulic Pump as Applied to Aircraft, by Dale Herman

The Modern Hydraulic Reservoir: How It Provides Micron-Range Filtration and Pump Supercharging, by W. W. Thayer

Aircraft-Engine Temperature Control, by W. A. Ray

High- and Low-Pressure Airplane Hydraulics in Europe, by Jean Mercier

Maintenance of Aircraft Hydraulic Systems in the Field, by R. E. Middleton

Centrifugal Casting of Steel, by S. D. Moxley

Some Characteristics of Rotary Pumps in Aviation Service, by R. J. S. Pigott

Effect of Combined High Temperature and High Humidity on the Corrosion of Samples of Various Metals, by W. L. Maucher and B. W. Jones

Necrology

THE deaths of the following members have recently been reported to headquarters:

BLOHM, AUGUST HENRY, September 3, 1944
CLARKE, CHARLES A., April 27, 1944
ELROD, HENRY E., July 18, 1944
HANSON, ALFRED E., July 30, 1944
HEIDENGER, HENRY W., August 19, 1944
HOFFMAN, SIMON, September 9, 1944
NIXON, THOMAS D., July 21, 1944*
OBERGFELL, HERBERT F., December 29, 1943
SCHOTT, RUDOLPH DONALDSON, March 25, 1944
TELFORD, MARSHALL H., September 11, 1944

* Died in line of duty.